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ORIGINAL ARTICLES.

I.—On the Mollusca of the Pleistocene Gravels in the Neighbourhood of Cambridge.

By Mrs. McKenny Hughes.

THE site of Barnwell Abbey has long been excavated for gravel. The pits have been easily accessible to collectors, and have for many years yielded large numbers of Mammalian bones, Mollusca, and a few plant-remains.

These gravels were noticed by the Rev. P. B. Brodie and Prof. Sedgwick in 1838.[1] Prof. Seeley gave a sketch of them in the Q. J. G. S. 1866, in which there was a list of the land and fresh-water shells drawn up by Mr. Dewick. They were described by Mr. Jukes-Browne in his essay on the Post-Tertiary deposits of Cambridgeshire, 1878, and in the Memoir of the Geological Survey.[2] A list of the species preserved in the Woodwardian Museum was given by Prof. Hughes in the Geological Magazine in 1883. Exact references to some of these papers and to others in which the deposits are mentioned will be found in Mr. Whitaker's list of works on the Geology of Cambridgeshire, privately printed for the Woodwardian Museum in 1873, and reissued with the Geological Survey Memoir above referred to. A list of shells from the Barnwell Gravel is given by Dollfus.[3]

Whenever any fresh excavations are made in this district, new evidence is generally obtained as to the relations of beds, and the distribution of the life of the period; and it seems desirable to place on record at once any additional facts observed in deposits which are being entirely removed, such as the Barnwell Abbey gravel, and to call attention to any hitherto undescribed sections, such as those near Barnwell Station, at Grantchester, or in the pits west of Barrington Green.

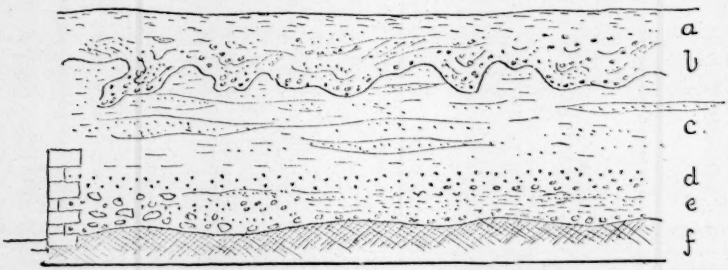
Within the last few years Barnwell Abbey has been acquired by Mr. Sturton, who has laid out the ground in building plots, having previously removed almost the whole of the surface gravel. Mr. Sturton has with great liberality presented to the University what remained of the old Abbey and a piece of the ground around it, and has offered every facility to geologists for examining the sections during the progress of the work. Thus an exceptional opportunity

[1] Trans. Camb. Phil. Soc. vol. viii. 1844, part i. p. 138.
[2] Explanation of Sheet 51 S.W. 1881.
[3] Le Terrain Quaternaire d'Ostende, etc., Bruxelles, 1884.

has been offered for observing the relative position of the beds in which the different species were more or less abundant. None of the shells were confined to definite zones; nor were they distributed through beds bearing any constant relation to one another; but, at varying horizons, and in different parts of the field, lenticular masses and pockets occurred, in which certain species were very abundant, while others were absent there which were common above or below, or at the same horizon close by; whereas, not far off they would be found mixed together in the same bed. In former excavations, in one part of the field, plant-remains were found in abundance near the base of the gravel. Among these were a few *Chara* spores and a quantity of leaves and twigs which are considered by Mr. Clement Reid to belong to one species of *Salix*—probably *S. repens*. From the recent diggings very few plant-remains have been obtained; only an obscure fragment here and there.

It is clear that gravel-pits of inconsiderable size opened in closely adjoining parts of the field might yield a very different group of fossils; but the removal of the whole showed that this depended upon small local variations of the same set of deposits. For instance, there were, in one case associated with Mammoth near the top, and in another resting on the Gault at the very base of the deposits (see

FIG. 1.—Section seen by Ancient Well North of Ruin, on site of Barnwell Abbey. Scale—10 feet to 1 inch.



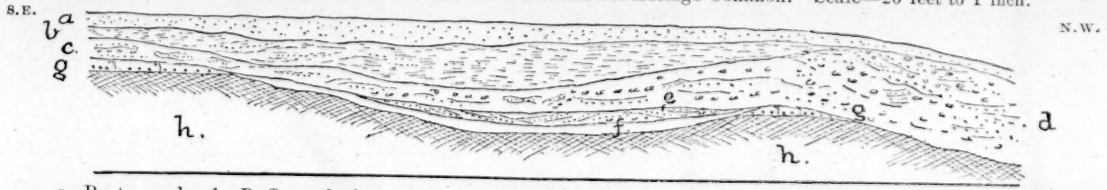
a, Surface soil, etc.; *b*, Irregular gravel; *c*, Fine sand and marl: *d*, Reddish sand; *e*, Coarse gravel consisting in places of large subangular flints with a few boulders derived from the drift and passing horizontally into fine beds of chalky gravel and marl full of shells, chiefly *Bythinia*, *Corbicula*, *Unio*, *Valvata*, *Planorbis*, etc.; *f*, Gault.

Section Fig. 1), lenticular marly beds containing shells and opercula of *Bythinia* in great abundance. In some places no specimen of *Corbicula* (*Cyrena*) could be found; still more often *Unio litoralis* was absent, although these shells occurred somewhere at every horizon. Except, therefore, in the case of very extensive excavations, generalizations, especially where founded largely on negative evidence, must be considered only as tentative.

In the gravel-pits at the other side of the Newmarket Road no shell-bearing beds are now exposed, although a few years ago *Unio litoralis* occurred abundantly in the N.W. corner of the pit, but lower than the level of the present workings.

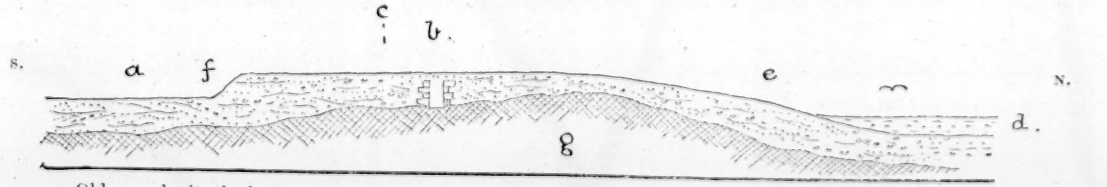
Following the gravel due north we come to the brick-pit at

FIG. 2.—Section in Brick-pit between Barnwell Station and Stourbridge Common. Scale—20 feet to 1 inch.



a, Rusty sand; *b*, Buff sandy loam, darker where damp, some cross-bedding, lines of more sandy loam weathering out; *c*, Gravel, split up by beds of sand and loam at S.E. end; *d*, Gravel: falling over bank to lower level of Stourbridge Common; *e*, White sand and gravel with shells, which runs higher further west; *f*, White marl, such as might be derived from the Chalk-marl, and bands and pockets of re-sorted phosphatic nodules; *g*, Remains of Chalk-marl and Cambridge Greensand running into *f*; *h*, Gault.

FIG. 3.—Section Across the Barnwell Abbey Gravel. Length of Section, 500 feet.



a, Old gravel-pit, the bottom partly refilled; *b*, Ancient well; *c*, Position of ruin; *d*, Alluvium, etc.; *e*, Gravel north of bank of Gault; *f*, The Barnwell Abbey gravel; *g*, Gault. Further west the Phosphate Bed comes on at a lower level than that at which the Gault occurs here, and further east, at a somewhat higher level, there is a capping of Chalk-marl.

Barnwell Station; here the gravel is seen resting on the Gault, which is in places troughed in such a manner as to suggest the beds of ancient streams (see Section Fig. 2).

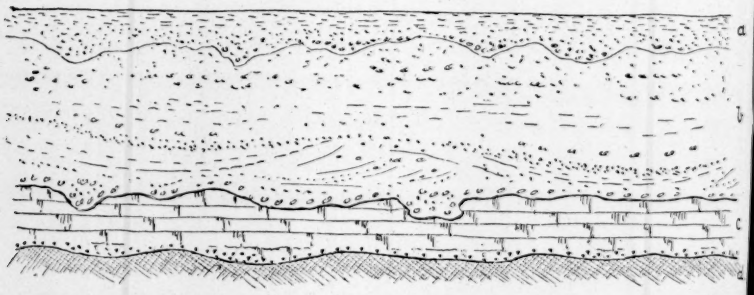
There seems to be one such old channel here at the margin of the gravel, running parallel to the present river-valley. *b*, *c*, *d*, and *e* of the section are river deposits which have filled it up; some of the looping is perhaps caused or increased by the decomposition of underlying chalky beds. The channel here and there cuts just into the top of the Gault, and patches of the overlying Chalk-marl and Phosphate Bed are left; the banks seem to have fallen in in places, and the gravel has sunk into the puddled surface of the clay, so that the Gault, Phosphate Bed and gravel are sometimes kneaded up together in the most irregular manner. The gravel (*c*) thickens out to the west, and falling over the slope to the lower ground forms the main mass of the bank next Stourbridge Common, and corresponds to the gravel near the Holy Well at Barnwell Abbey, which in like manner lies on the west slope of a bank of Gault (see Fig. 3).

This western portion, both here and at Barnwell Abbey, forms the margin of a lower terrace, which being directly derived from the higher level gravels, can hardly be distinguished from them on the ground. The deposit in which the shells occur at Barnwell Station (*e*) is older than this flanking gravel, as, at Barnwell Abbey, the shell-bearing strata are older than the gravels west of the Gault ridge, and between it and the river. When, however, we have to consider the relative age of the shell-beds at Barnwell Station and those at Barnwell Abbey, we find that the question is more complex. The lie of the ground seems to point to their being part of the same mass, but the character of the deposits seems to indicate that though they belong to approximately the same age, they were nevertheless laid down under somewhat different conditions.

With the interruption of the lower level gravels of the Cam Valley, described by Mr. Jukes-Browne, we find beds similar to

Fig. 4.—Section South of Grantchester.

Scale—10 feet to 1 inch.



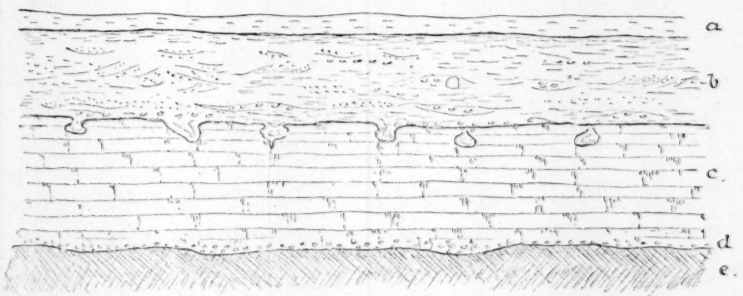
a, Surface soil and rusty gravel from which the Chalk has been dissolved out; *b*, Chalky gravel and marl with pans of peaty silt and bands full of land and freshwater shells; *c*, Chalk-marl and Phosphate Bed; *d*, Gault.

those at Barnwell covering a large area near Shelford, where also *Corbicula fluminalis* is found, and extending by Trumpington to the well-marked terrace of Grantchester

The Grantchester gravel (see Section Fig. 4) occurred in irregular masses troughed into the underlying Chalk-marl, and was exposed by the removal of the whole of the surface in the process of digging for phosphate nodules. It was not clear that it bore any relation to the existing geographical features; but its irregularity and the presence of pans of decomposed vegetable matter and of masses of shells buried in chalky loam, seemed to indicate accumulations along the shifting channels of a river wandering over a tolerably wide area, and deriving much of its material from older gravels, from Boulder-clay, and even directly from the Chalk-marl which it here and there touched in its course. All the shells in the Woodwardian Museum were obtained from one rich deposit of small extent close to the farm track, just beyond the S.W. corner of the camp, at a depth of about 5 to 8 feet from the surface. This pit is now filled up, and although there are here and there openings from which sand and gravel are being dug, no shells have been found in them; nor are any beds now exposed exactly similar to those from which the shells were formerly obtained. The list of Mammalian remains and shells given in Column II. p. 202, has not hitherto been published.

Beyond Grantchester, about four miles to the south-west, the village of Barrington stands on a terrace on the left bank of the River Rhee. This terrace consists principally of loam derived from the Chalk-marl with lines and lenticular beds of sand and gravel to a depth of from 5 to 10 feet.

Fig. 5.—Section seen in pit north of Windmill, near Westgate Farm, Barrington. Scale—10 feet to 1 inch.



a, Surface soil. 1′—2′; *b*, Chalky loam and sand, with small lines and lenticular beds of gravel. At the southern or lower end of the digging the gravel and sand is looped into the top of the underlying Chalk-marl. 6′—7′; *c*, Chalk-marl; *d*, Cambridge Greensand; *e*, Gault.

The gravel does not appear on the 1-inch Survey Map, probably because at the time that map was made there was nothing at the surface to distinguish the loam which belonged to the gravel from the decomposed surface of the marl, etc. In subsequent phosphate

diggings, however, on the north-east side of the village, this deposit was exposed and described by the Rev. O. Fisher,[1] and referred to in the Survey Memoir.[2]

About a mile and a quarter W.S.W. of these pits, north of the Windmill, on the other side of Barrington Green, extensive excavations for phosphate have recently exposed other sections in what is the continuation of that terrace, or if now cut off from it by the little valley west of Barrington Green, was originally part of the same.

From the character of the workings, the whole of the deposits belonging to the gravel age can be seen down to the base, where they rest upon the Chalk-marl (see Section Fig. 5). They consist largely of materials derived from the Chalk-marl and from the Boulder-clay, which at that time must have covered a much wider area than now on the adjoining hills. A somewhat larger admixture of far-travelled fragments from the drift might be expected, and as a matter of fact is generally found, in all gravel deposits of the district which occur on higher and older terraces, or nearer the hills.

The portions of the Barrington Gravel, which are of the same coarseness as that of Barnwell, do not differ much from it in composition; in both cases a large proportion of the material consists of ferruginous subangular flints.

The Barrington deposit is exceptionally rich in the number and variety of its Mammalian remains. Small pieces of bone occur through the whole, but the largest and best-preserved bones lie in irregular masses of gravel near the base. In one place just above the Chalk-marl there was a boulder of quartzite about 9 inches in diameter resting upon a large limb bone. The bones are generally scattered and mixed, but occasionally there seems to be evidence of associated remains. Among the valuable specimens secured by Mr. Keeping's skill for the Woodwardian Museum, there are several whole lower jaws of Hippopotamus and a nearly perfect skull of Hyæna. It will be seen on comparing the lists of fossils given below (p. 202), that the Mammalian remains from this pit at Barrington (Column IV.) agree with those from Barnwell Abbey (Column I.), with the exception of *Arvicola*, determined by Mr. Oldfield Thomas, which has not been found at Barrington, and of Reindeer, the occurrence of which at Barnwell rests on the determination of a small fragment of antler. Horse occurs in all four localities.

Bison priscus, *Cervus megaceros*, *C. tarandus*, *Hippopotamus amphibius* (*major*), *Rhinoceros leptorhinus*, and *Meles taxus*, have not been found at Grantchester, but these diggings were unfortunately not so carefully watched as they might have been. Bones have been obtained from the pit near Barnwell Station, but they have, generally, been too fragmentary for determination. The following species have, however, been made out, Red Deer, Mammoth, Rhinoceros and Horse.

At Barrington the shells occurred in rapidly thinning and thicken-

[1] Q.J.G.S. vol. xxxv. 1879, p. 670. [2] pp. 94-5.

ing beds of loam and sand in the same manner as at Barnwell Station, but not indiscriminately through coarse gravel and finer deposits as at Barnwell Abbey.

The shells of Barnwell Station (Column III.) and Barrington (Column IV.) seem to represent marginal deposits such as are seen along the edges of ponds and rivers at the present time, occasionally encroached upon by river floods which swept them into holes and embayed corners.

This is suggested by the accumulation of the smaller and lighter shells, just as now seen on the edge of the flood-water, and by the great abundance of *Pupa marginata*, while the rest of the shells are quite consistent with this view. *Anodonta* is rare and usually imperfect.

The shells of Barnwell Abbey (Column I.) and of Grantchester (Column II.) seem to belong rather to the main channel of the river. *Unio* and *Corbicula*, which like river-beds, occur at Barnwell Abbey and Grantchester, but not at Barnwell Station or Barrington. *Pupa*, the characteristic shell of the other two localities, is comparatively rare at Barnwell Abbey and Grantchester.

There is a marked agreement between the Barnwell Abbey and Grantchester Mollusca. All the species which are individually numerous in either locality are common to both. Those which are peculiar to one of the two localities are rare forms. Thus *Hydrobia marginata*, Mich., occurs at Barnwell Abbey, but has not been found at Grantchester. *Limax* is recorded only from Barnwell. Single specimens of *Planorbis nitidus*, Müll., *P. fontanus*, Light., *Patula ruderata*, Müll., *Helix lamellata*, Jeff., *Vertigo pusilla*, Müll., *V. edentula*, Drap., *V. minutissima*, Hart., and *Cæcilianella acicula*, Müll., have been found at Barnwell Abbey and there only. On the other hand, *Planorbis nautilus*, Linn., *Helix obvoluta*, Müll., and *H. aculeata*, Müll., are as yet peculiar to Grantchester. A more careful search would, however, probably result in filling up most of the gaps in both lists (see pp. 200—202) :—

I must here acknowledge the kind help which I have received from Mr. Cooke in drawing up the list of shells, and in finding the range of various species.

I am also much indebted to Mr. Dewick for the trouble he has taken in determining my specimens of *Limax* and some other species, by comparison with those in the Natural History Museum, and also for lending me his rarer specimens for examination.

Professor Rupert Jones has kindly determined the Ostracoda for me. He remarks that he has found *Candona compressa*, Koch, in Post-Tertiary beds in Berkshire, Cambridgeshire, also at Fisherton, near Salisbury, from the raised beach of Portland (Prestwich Coll.), and from the Chara Bed near Hitchin (Blackmore Coll.). *Candona candida*, Müll., he says, is very common, both Recent and Post-Tertiary.

An explanation of the isolated or rare occurrence of certain forms in the ancient river deposits is suggested by what is seen at the present time along the Cam above Cambridge, where the artificial

List of Fossils from Gravels in the Neighbourhood of Cambridge.	Barnwell Abbey.	Grantchester.	Barnwell Station.	Barrington.
	I.	II.	III.	IV.
Plants.				
Spores and stems of *Chara*	x			
Salix (probably *S. repens*). Twigs and leaves.	x			
Invertebrata. Crustacea (Ostracoda).				
Cypris reptans, Baird (see Jones, Post-Tert. Entom. 1874, p. 128)	....	x		
Candona compressa, Koch (*ib.* p. 135)	x			
——— *candida* Müll. (*ib.* p. 135)	x			
Invertebrata—Mollusca. Lamellibranchiata.				
Sphærium corneum, Linn. (Not very large, mostly young.)	x	x	....	x
S. lacustre, Müll, York Museum	x			
Pisidium amnicum, Müll. (Very abundant. Valves adh.)	x	x	x	x
——— *fontinale*, Drap. (Abundant. Valves adherent.)	x	x	x	x
——— ——— var. *Henslowana*, Sheppard. (Abundant at Grantchester.)	x	x	....	x
——— *pusillum*, Gmel. (In Mr. Dewick's and also in Mr. Tomlin's Collection from Barnwell Abbey. Several specimens in the Woodwardian Museum from Grantchester.)	x	x		
Corbicula fluminalis, Müll. (Usually of a small size. Great variety in size, shape, texture and sculpture. Very abundant at Barnwell Abbey and Grantchester. Valves often adherent and ligament preserved.)	x	x		
Unio pictorum, Linn.	x	x		
——— ——— var. *limosa*, Nils.	x	x		
——— *litoralis*, Lamk. = *U. rhomboideus*, Schröt. (Great variation in size, shape and thickness. Both valves often adherent and ligament preserved.)	x	x		
Anodonta, sp.	....	....	....	x
Gasteropoda.				
Bythinia tentaculata, Linn. (Varies much in size. Many young specimens. Opercula very common in places. Sometimes found still in the shell.)	x	x	....	x
Hydrobia marginata, Mich. (Rare.)	x			
Valvata piscinalis, Müll. (Very abundant. Varies very much in size and shape. Many young specimens.)	x	x	x	x
——— *cristata*, Müll. (Not common.)	x	x	....	x
Planorbis nitidus, Müll. = *P. lineatus*, Walker. Very rare. (One specimen in Mr. Tomlin's Collection.)	x			
——— *fontanus*, Lightf. = *P. nitidus*, Müll. (Jeff.) British Conchology, vol. i. p. 81. Mr. Dewick has a single specimen in his Collection, from Barnwell.	x			
——— *nautilus*, Linn.	....	x		
——— *glaber*, Jeff. (Very rare.)	x	x		
——— *spirorbis*, Müll. (Common at Barnwell Junction.)	x	x	x	x
——— *vortex*, Linn. (Rare.)	x	x		
——— *carinatus*, Müll. (Rare.)	x	x?	x	
——— *complanatus*, Linn. (Fairly abundant.)	x	x		

GASTEROPODA—*continued.*	I.	II.	III.	IV.
Planorbis contortus, Linn. (Rare.)	x	x	x	
Physa hypnorum, Linn. (Single specimen from Grantchester, in the Woodwardian Museum. One specimen from Barnwell Abbey in Mr. Tomlin's Collection.)	x	x		
——— *fontinalis*, Linn. (Three or four good specimens from Barnwell Abbey in Mr. Tomlin's Collection, and one specimen from Grantchester in the Woodwardian Museum.)	x	x		
Limnæa peregra, Müll. (Not common.)	x	x	x	x
——— *auricularia*, Linn. (Very common. Spire often much intorted. Two specimens from Barnwell Abbey slightly scalariform. Varies much in size. Lines of growth often strongly marked.)	x	x		
——— *stagnalis*, Linn. (A few specimens only from Barnwell Abbey. Fairly common at Grantchester.)	x	x		
——— *palustris*, Müll.	x	x	x	x
——— *truncatula*, Müll. (Common at Grantchester. Many very small specimens.)	x	x	x	x
Ancylus fluviatilis, Müll.	x	x		
——— *lacustris*, Linn. = *oblongus*, Forbes & Hanley.	x	x		
LAND SHELLS.				
Limax agrestis, Linn.	x			
——— *arborum*, Bonch. Chant. (Mr. Dewick determined two specimens found by me.)	x			
——— *lævis*, Müll. (Two specimens found by myself.)	x			
Succinea putris, Linn. (Very large specimens at Barnwell Abbey and Grantchester.)	x	x	x	x
——— *elegans*, Risso.	x	x	x	x
——— *oblonga*, Drap.	x	x	x	
Hyalina cellaria, Müll.	x	x		
——— *nitidula*, Drap.	x	x		
——— *radiatula*, Alder.	x	x		
——— *nitida*, Müll.	x	x		
——— *crystallina*, Müll.	x	x		
Conulus fulvus, Drap.	x	x		
Patula rotundata, Müll. (Rare.)	x	x		
——— *ruderata*, Studer. (A single specimen found by Mr. Dewick.)	x			
——— *pygmæa*, Drap. (One reversed specimen found at Barnwell Abbey by Mr. Dewick.)	x	x		
Helix (*Anchistoma*) *obvoluta*, Müll. (One full grown and one young specimen in the Woodwardian Museum.)	.....	x		
——— (*Acanthinula*) *aculeata*, Müll. (Twelve specimens in the Woodwardian Museum.)	.....	x		
——— (———) *lamellata*, Jeff. (A single specimen found by Mr. Dewick.)	x			
——— (*Vallonia*) *pulchella*, Müll. (Very abundant.)	x	x	.....	x
——— (*Fruticicola*) *hispida*, Linn.	x	x	x	x
——— (———) *concinna*, Jeff. (One reversed specimen found at Barnwell Abbey by Mr. Dewick.)	x	x	x	x
——— (———) *fruticum*, Müll. (Rare.)	x	x		
——— (*Chilotrema*) *lapicida*, Linn. (Three specimens from Barnwell Abbey. One in Mr. Dewick's Collection and two in the Woodwardian Museum. Two specimens from Grantchester in the Woodwardian Museum.)	x	x		
——— (*Arionta*) *arbustorum*, Linn. (Varies very much. Many of the shells distorted and injured.)	x	x		
——— (———) var. *alpestris*, Ziegler. (Common at Barnwell Abbey.)	x	x		

List of Fossils from Gravels in the Neighbourhood of Cambridge—*continued.*	Barnwell Abbey.	Grantchester.	Barnwell Station.	Barrington.
	I.	II.	III.	IV.
Helix (*Tachea*) *nemoralis*, Linn. [Not very common. Varieties of banding, 12345, 00345, (12345), 1(23)45, 00330, 003(45), 10345.]	x	x	.....	x
——— (*Xerophila*) *cricetorum*, Müll. (Common at Barnwell Abbey and Grantchester.)	x	x	x	x
——— (———) *virgata*, Da C. (Common at Barrington.)	.....	.....	.....	x
——— (———) *caperata*, Mont. (Very rare.)	x	x	.....	?
Buliminus montanus, Drap.	x	x	x	
——— *obscurus*, Müll. (One specimen from Barnwell Abbey in the York Museum, and one from Grantchester in the Woodwardian Museum.)	x	x		
Pupa marginata, Drap. (Very abundant at Barnwell Station and at Barrington.)	x	x	x	x
Vertigo antivertigo, Drap.	x	x		
——— *Moulinsiana*, Dupuy.	x	x		
——— *pusilla*, Müll. (One in Mr. Tomlin's Coll.)	x			
——— *augustior*, Jeff.	x	x		
——— *pygmæa*, Drap.	x	x		
——— *edentula*, Drap. (One found by Mr. Dewick resembles var. *columella* of Jeffreys.)	x			
——— *minutissima*, Hartmann. (One specimen found by Mr. Dewick.)	x			
Balea perversa? Linn. Young. Mr. Dewick's Coll.	x			
Clausilia rugosa, Drap.	x	x		
——— *pumila*, Ziegler. (Described in former lists as *C. biplicata*.)	x	x		
Azeca tridens, Riet. (Rare.)	x	x		
Zua lubrica, Müll.	x	x	x	x
Cæcilianella acicula, Müll. (One specimen found by Mr. Dewick. Young. Filled with gravel.)	x	x		
Carychium minimum, Müll. (Common. Several of the specimens found inside *H. arbustorum* and *H. nemoralis*.)	x	x		
Cyclostoma elegans, Müll. (One specimen only, found by me in the Mammaliferous gravel of Barrington.)	.....	.....	.....	x
VERTEBRATA.				
Bison priscus, Bojan.	x	.....	.....	x
Bos primigenius, Bojan.	x	x	.....	x
Cervus megaceros, Hart.	x	.....	.....	x
——— *elaphus*, Linn.	x	x	x	x
——— *tarandus*, Linn.	x			
Elephas antiquus, Falc.	x	?	.....	x
——— *primigenius*, Blum.	x	x	x	x
Equus caballus fossilis, Meyer.	x	x	x	x
Felis spelæa, Goldf.	x	x	.....	x
Hippopotamus amphibius, L. = *major*, Cuv.	x	.....	.....	x
Hyæna crocuta = *spelæa*, Goldf.	x	x	.....	x
Rhinoceros leptorhinus, or *tichorhinus*, Cuvier.	x	.....	x	x
Ursus spelæus, Blum.	x	x	.....	x
Meles taxus, Owen.	x	.....	.....	x
Arvicola agrestis? sp.	x	x		

diversion of the river has produced effects which must have been common in the case of the uncontrolled rivers of former times. On Sheep's Green there are many small ponds which represent deserted portions of the old river-bed; in these many of the less common and irregularly distributed freshwater shells occur—abundantly in one—rarely, or not at all, in another. For instance, we find *Bythinia Leachii* there, as well as in the ditches further south. In one of the ponds seven species of *Planorbis*, including the two rare forms *P. nitidus*, Müll., and *P. fontanus*, Light., also *Valvata cristata*, Müll., and many of the *Pisidia*, are found.

Mr. Tomlin, who has thoroughly searched that locality, informs me that two of the ponds are far richer than any of the others, and that he never met with the two rare species of *Planorbis*, mentioned above, elsewhere in this neighbourhood, except odd live specimens in some of the other Sheep's Green ponds. He never found them anywhere down the river.

Along the margin of these pools *Carychium minimum*, Müll., and *Hyalina nitida*, Müll., abound. Now and then, when the river is in flood, the whole Green is under water, and at such times many of the shells in these ponds and ditches must be carried away and mixed with the common river shells.

From analogy, therefore, it would appear that the winding about of a frequently flooded river, over an alluvial plain, in which ponds remained where the deeper parts of the old river-bed had been, would most easily account for the difference in the facies of the gravel-shells in the different localities.

A careful study of the distribution and mode of occurrence of the gravel fauna and flora ought to give us some clue to the geographical changes which have affected the incoming and disappearance of the various forms of life.

The great majority of Mollusca from these gravels are living in this district at the present day. A few are locally extinct. Of these some are confined to the north and some to the south of England, whilst some have disappeared from the British Isles altogether. Some of the Mammals, but none of the Mollusca, are totally extinct.

The shell which seems to indicate the greatest change of conditions is the *Corbicula* (*Cyrena*) *fluminalis*, Müll.

It lives at the present time in Sicily,[1] in the rivers of Asia Minor and Syria and in the Nile. It seems to have made its first appearance in Britain in the time of the deposition of the Norwich Crag, from which it is described and figured by Mr. Searles Wood,[2] as *Cyrena consobrina*.[3]

It is recorded from the Weybourn Crag and from the Forest Bed. In the north of England it is found in the gravels of the Humber, of Kelsea Hill, and Hessle; in the basin of the Thames and the adjoining district of Essex it has been recorded from Suttonness, Clacton-on-Sea, Copford, Greys, Ilford, Erith, and Crayford, Faver-

[1] Geol. Eng. and Wales, H. B. Woodward, 2nd edition, p. 478.
[2] S. V. Wood, "The Crag Mollusca," vol. ii. p. 104, tab. 11, fig. 15.
[3] Tylor, Q.J.G.S. vol. xxv. 1869, p. 66.

sham and Reculvers, and by Prof. Prestwich[1] from Summertown near Oxford. It also occurs in the gravels of the basin of the Cam and Ouse. It occurs in Belgium and in France in the ancient alluvium of the Seine and Somme. This therefore appears to be a southern shell, which had formerly a more northern range.

The six following shells are extinct in Britain, but most of them have a wide range in Europe and Asia:—

Unio litoralis, Lamk., is, according to Moquin Tandon,[2] found in almost all the rivers of France. Kobelt records it also from Spain, Morocco, and Algeria.

Unio pictorum, var. *limosa*, Nils., according to Moquin Tandon, occurs in almost all the rivers and brooks of Northern France.

Hydrobia marginata, Mich., lives in France, says the same author, on dead leaves under water and on aquatic plants at Var, Vaucluse, L'Aveyron, the Haute Garonne and the Jura.

Helix (*Fruticicola*) *fruticum*, Müll., is found all over Europe with the one exception of England. It ranges as far north as St. Petersburg.[3] Moquin Tandon[4] says that it is found over almost all northern and central France, but that it does not occur in the southern part.

Miss Esmark records it from North and South Norway, Sweden, and Finland. She says, "It is not very common, but plentiful where it occurs."[5] I am told by Mr. Cooke that it occurs also in North-West and East Siberia and the Altai Baikal district.

Patula ruderata, Studer, has a very wide range. Kobelt records it from the Caucasus, Europe, Northern Africa, and the whole of Western Asia. Jeffreys from Kamschatka, South Russia and Austria, and North Japan.[6] Clessin says that it lives in the mountainous parts of Germany and in the Alps. Moquin Tandon says it is found under stones and dead leaves in the Jura. Miss Esmark records it from Norway, Sweden, and Finland, and remarks that it is "one of our most common species, which goes as well to the far north as on our highest mountains, wherever it is possible for any Molluscs to live."[7] Mr. Cooke informs me that it is found also in West and East Siberia, Amurland, North China, Japan? and North Persia.

Clausilia pumila, Ziegler, is, according to Clessin,[8] distributed over a great part of Germany, but is most common in the North. Its range is eastward to the Siebenbürgen; southward to Croatia; northward to Livland and Sweden; it finds its western limit in Germany, and does not occur in England except as a fossil.

It has hitherto been recorded from the gravels of Cambridge as *C. biplicata*, but Mr. B. B. Woodward[9] has shown that all the shells referred to that species are really the *C. pumila* of Ziegler.

[1] Geol. Mag. n.s. Vol. IX. 1882, p. 49. [2] Hist. Nat. des Mollusques.
[3] Clessin, Deutsche. Excurs. Mollusken-Fauna, p. 166.
[4] *Op. cit.* vol. ii. p. 198. [5] Esmark, Journ. Conch. vol. v. pp. 106, 126.
[6] Jeff. Brit. Conch. vol. v. Supplement, p. 158.
[7] Journ. Conch, vol. v. p. 104. [8] *Op. cit.* p. 312.
[9] Since this paper was sent to press a valuable communication has been made by Mr. Woodward to the Geol. Assoc. (March 2, 1888) on the shells of the Barnwell Gravel, founded chiefly on Mr. Dewick's Collection. *Sphærium lacustre* has been inserted above on his authority.

There are also in the gravels described some six or eight shells which we do not now find in the neighbourhood of Cambridge, but which occur elsewhere in the British Isles.

Succinea oblonga, Drap., is mentioned by Gwyn-Jeffreys[1] as rare in Wales, Scotland and Ireland and in England is recorded from Braunton Burrows in Devonshire only. Its habitat is "dry ditches near the sea-coast."

Helix (*Anchistoma*) *obvoluta*, Müll. This shell, says Jeffreys, lives on stumps and at the roots of trees in woods in Hampshire. Da Costa and Taylor give it a somewhat wider range in the south of England, mentioning also Surrey and West Sussex.

Jeffreys observes that it occurs in France, Germany, Switzerland, and Lombardy, but that it does not seem to inhabit the extreme north and south of Europe.[2]

Clessin says that it is less common in the north than in the south of Germany, and he records it also from Bohemia.[3] This occurrence of *H. obvoluta* in the gravels shows that it is not a form now advancing from the south, but is, on the contrary, a species which is dying out in England, but still survives in the south.

Helix (*Acanthinula*) *lamellata*, Jeff., is now found only in the north of England, Anglesey, north and west of Scotland, Ireland, Sweden. Clessin[4] records it from North Germany. In this shell we have, in contrast to the last-mentioned species, an example of a form which has become extinct in the south of England, but is still fairly plentiful in the north.

Vertigo angustior, Jeff. The habitat of this rare shell is "in the roots of grass in marshy ground." Jeffreys found it near Swansea and in the rejectamenta of the river Avon at Bristol. He records it from Tenby, Battersea Fields, and Ireland, the north-east and south of France, Germany, Switzerland, and from Lugano in Italy.[5]

Mr. Charles Ashford, who kindly examined a specimen which I had discovered at Barnwell, found on comparing it with recent *Vertigo pusilla* in his collection from Yorkshire, that amongst them was one undoubted *Vertigo angustior* which he had hitherto overlooked. I have found it in Westmoreland also. Miss Esmark records it from South Norway and Sweden.[6]

Possibly the following species did not appear in England till after the deposition of these gravels.

Helix (*Fruticicola*) *cantiana*, Mont., does not seem to occur in the gravels. It is very common round Cambridge at the present time, and is found in the north and south of England, but not in Scotland or Ireland. It lives in France, Belgium, parts of Germany, Italy, Illyria, and Sicily.

It is doubtful whether *Helix* (*Fruticicola*) *rufescens*, Pennant, is found in the gravels. It is now widely distributed over England, and occurs in Ireland, but not in Scotland.

Helix aspersa, Müll., is not recorded from any of the localities

[1] Brit. Conch. vol. i. p. 154.
[2] *Op. cit.* p. 230.
[3] Deutsch. Exc. Moll.-Fauna, p. 134.
[4] *Op. cit.* p. 129.
[5] Brit. Conch. vol. i. p. 266.
[6] Journ. Conch. vol. v. p. 127.

given in the list, nor can I find mention of it from similar gravels elsewhere.

Mr. Gloyne in his paper on the Geographical Distribution of the Mollusca,[1] says, "*Helix aspersa* attains a much larger size in Italy than in England. It is very difficult to believe that so abundant a British species has been introduced; but judging from the reduced size of English specimens, England would, to say the least, not appear to possess the most favourable climate for this mollusc."

Jeffreys says, "It does not appear to inhabit the north of Europe, nor Germany . . . but its range extends southwards through France to Sicily, as well as to Spain, Algeria, and the Azores.[2]

It occurs also in many widely separated parts of the world to which it is known to have been artificially introduced. As, for instance, Mauritius, S. Australia, Valparaiso, Rio in Brazil, and sea-ports along the east coast of N. America. The only evidence we have bearing upon the time of its first appearance in Britain is its plentiful occurrence in the Roman rubbish pits at Chesterford and elsewhere about Cambridge at such a depth and in such a manner as to preclude the possibility of its having got in subsequently.[3]

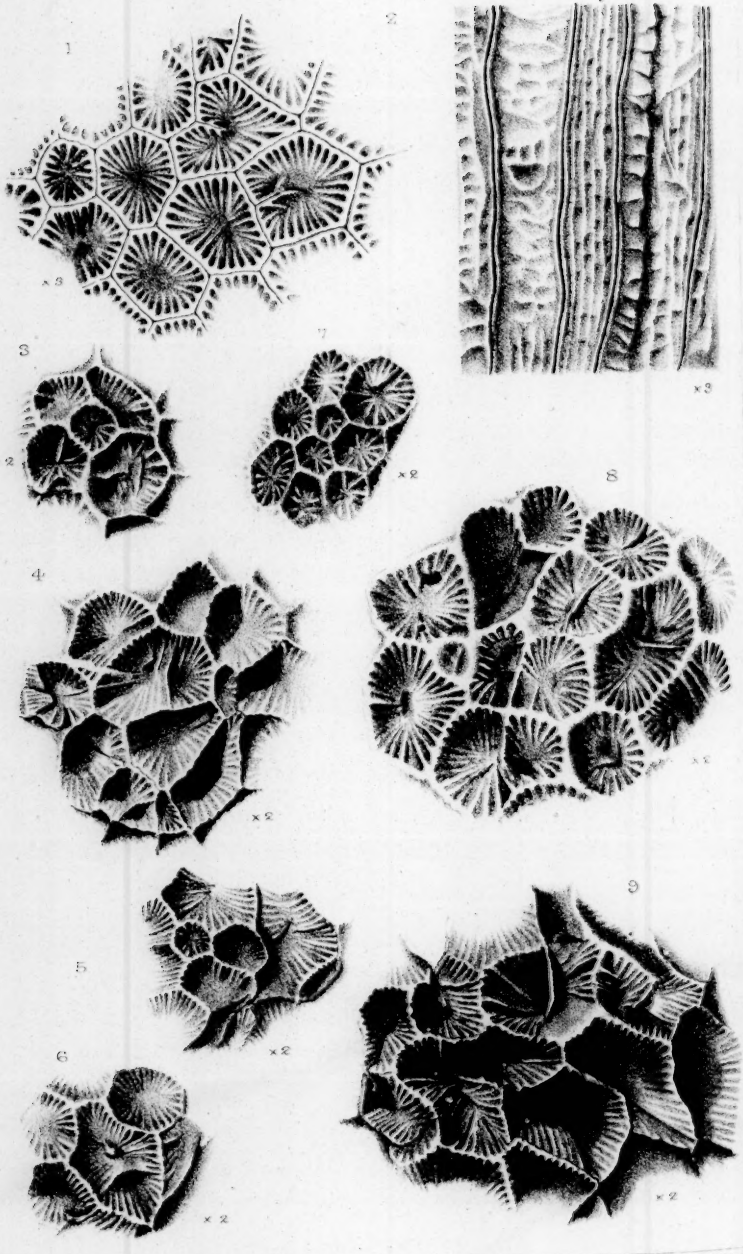
Helix? pomatia, Linn., which lives now in the neighbourhood of Shelford, has not been found in any of these gravels, and I have never noticed it among the Roman remains of this district, even where shells of *H. aspersa* appear to have been thrown in in large quantities.

Helix (*Arionta*) *arbustorum*, Linn., is now found with *Helix* (*Tachea*) *nemoralis* in the Grantchester woods. It also lives under the willows close to the river, and is seldom found far from the water. A few days ago I noticed numbers of shells of this snail freshly broken by birds lying round the stones on which they had been smashed, all along the bank of the ditch near the bathing sheds on Coe Fen. This species is extremely common in the gravels of Barnwell Abbey and Grantchester. It probably found a hiding-place as at present under willows, of which remains, as we have seen above, occurred so abundantly in one part of the pit at Barnwell Abbey.

Cyclostoma elegans, Müll. I have found one specimen of this shell undoubtedly in the Mammalian gravel of Barrington. It does not now live in the immediate neighbourhood of Cambridge. I found quantities of dead shells, many with the opercula in place, several feet from the surface, in a tumulus of pre-Roman date, at Upper Hare Park, near Six Mile Bottom.

It appears, therefore (see pp. 203—204) that among the shells of the Cambridge gravels we have no fewer than 6 species which are no longer found in Britain. Several species which I have mentioned (see p. 205) have been found in the gravels, but have now disappeared from this district, though they occur in other parts of England, and some species which are common near Cambridge at the present time are absent from the gravels (see p. 205).

[1] Journ. Conch. vol. i. p. 289. [2] Brit. Conch. vol. i. p. 182.
[3] See also B. B. Woodward, Science Gossip, May, 1883, pp. 115, 237.



F.C.Knight del et lith.

West, Newman & Co imp

Heterastræa.

It will be seen, also, that of the locally extinct Mollusca, as in the case of the Mammalia, some are distinctly northern, some southern forms, and some have an extensive range from north to south. Considering the wide distribution of the forms, both extinct and living, it is not safe, without taking into account the habitat and range of every species, to generalize upon the climatal conditions of the age. The collective evidence which we gain from the Mollusca as to the climate of the period is more reliable than that offered by the Mammalia, because the various northern and southern Mammals could migrate to and fro with the changing seasons; but the molluscs once having found their way to a locality would remain there until they were slowly driven away by unfavourable conditions. The two shells of most pronounced southern origin, *Corbicula fluminalis* and *Unio litoralis*, being fresh-water forms, would not be affected by changes of temperature so soon as land-shells.

With regard to geographical changes, the whole gravel fauna seems to point to continental conditions, when Europe was connected with Africa, and England was united with France and Belgium. The formation of the British Channel would put an end to the migration of the larger animals, and would cut off the species, which had here reached their furthest limit, from the region of their greatest development. These species, being thus isolated, would in time give way to the more vigorous forms, which were better fitted to their surroundings, and would not be affected by such changes.

II.—On *Heterastræa*, a new Genus of Madreporaria from the Lower Lias.

By Robert F. Tomes, Esq.

(PLATE VII.)

DURING the interval of ten years which has elapsed since my paper on Liassic Madreporaria was read at one of the meetings of the Geological Society, a great many specimens of Liassic *Isastræa* and *Septastræa*, chiefly from the Vale of Evesham, have come into my hands, and with this abundance of material I have examined anew the several species, and have arrived at the results contained in the present communication.[1] When making these examinations, I have been invariably struck with the absence of a distinct and well-defined basal wall and epitheca. Further observation also showed that these Liassic forms differed from other *Isastræa* in having occasional elongated calices, like those of *Latimæandra*. With the latter genus some of the Liassic *Isastræa* were supposed (though as it now appears erroneously) to hold a near relationship, and one species received the (at that time) appropriate specific name *latimæandroidea*. With this the supposed resemblance ended; for gemmation, which in *Latimæandra* is calicinal, was found to be always marginal in the Liassic forms.[2] Fuller investigation brought to

[1] More than seventy specimens have been examined and contributed to the results made known in this paper.

[2] It has become necessary that gemmation in the genus *Isastræa* should receive further attention. It has been variously stated both by Prof. Duncan and by me to

light other characters. A great development of endothecal structure sometimes almost filled up the loculi, and the walls of the corallites were observed to be of great thickness. Horizontal sections gave the proper interpretation of these thickened walls, and it was often seen that there was not only a fine line where the walls of the corallites came in contact, but that there was occasionally a visible interval between them. In this particular they resembled *Septastræa*, while at the same time their increase was by gemmation. Closer observation revealed the fact that there was both gemmation and fissiparity in nearly all the species examined; and, in a word, that they possessed characters which were inconsistent with both *Isastræa* and *Septastræa*, and formed a group of themselves.

Before proceeding to define the characters of the group above indicated, I take the opportunity of making some remarks which bear, though only generally, on the species under consideration.

Having repeatedly, both on former occasions and in the present communication, followed Milaschewitsch in the use of a word which is rendered in English by the word rejuvenescence, I am induced to give the following explanation of the process, because it is absolutely necessary that there should be a very clear conception of its importance in one of the genera of which I shall speak. That genus is *Elysastræa*. That it is not merely intermittent growth, and that it is not gemmation, has been most clearly shown by Milaschewitsch, but what really gives rise to it has not been explained by him. It was certainly noticed by Ehrenberg, and was long ago known to Dana, though he does not appear to have fully understood its nature. In the third volume of the American Journal of Science (second series) he speaks as follows:—

"In some Cyathophyllidæ the process of death goes on interruptedly, as explained by Ehrenberg. The tissues of the polyp disappear at intervals from the sides of the corallum, or become dead, leaving a row of unoccupied cellules; then the animal goes on to increase from its contracted size, without refilling the cellules; the corallum consequently becomes covered with encircling ridges, or appears as if formed of a series of inverted cones. In some cases, as in the species referred to the genus *Strombodes*, the living portion becomes retracted at intervals to the very centre, all the rest dying, and afterwards the animal grows again and spreads to its original

take place within the calice, as well as on the margin of the wall which surrounds it. Thus in the descriptions of *Isastræa endothecata* and *I. latimæandroidea*, Prof. Duncan says it is marginal ("on the margin" are the words made use of in the description of the latter species). More recently, however, he has asserted that "the gemmation of *Isastræa* certainly does not take place between the walls of corallites, but within the calicular margin; it is between the margin and the centre of the calice." I am not aware that it has ever been spoken of as occurring between the walls, though I, as well as Prof. Duncan himself, have spoken of it as occurring both *inside the calice and on the margin of the wall*. MM. Milne Edwards and Haime (Hist. Nat. Coral. vol ii. p. 526) speak of it in these words, "Les polypierites se multiplient par gemmation calicinale et submarginale," while M. de Fromentel says it is "submarginale." The present communication by removing the Liassic species from the genus *Isastræa* altogether, will materially lessen the difficulty of future classification.

diameter, and thus it forms actually one low inverted cone upon another. This peculiarity (probably an occasional result of the exhaustion which follows reproduction) cannot properly be considered a generic distinction."

In his "Structure and Classification of Zoophytes," page 65, after speaking of the process of dying or removal below, he says, "It is obvious from the preceding, that the polyp, which is the germ of a compound Zoophyte, loses its identity, and cannot be said, in any proper sense, to have the long life which is attributed to the full grown Zoophyte itself; or else we might have among the huge Astræas of the Red Sea, polyps that were contemporaries with the builders of the Pyramids." The polyp, however, "which is the germ of a compound Zoophyte," may lose its identity, and most likely does, by the process of gemmation, but not by rejuvenescence, which under no circumstances, as explained by Milaschewitsch, increases the number of corallites, and it is certainly rejuvenescence, of which Dana was then speaking.

It is when the contraction of the polyp takes place very irregularly, that the true nature of the process becomes most easily determined. If the shrinking of the soft tissues of the polyp is wholly on one side, and very great in degree, so that the visceral cavity is drawn out of the centre of the calice, then the constricted side of the animal will be lifted out of the loculi in the process, but that side which has undergone no such contraction may be very little interfered with. In such a case entirely new septa will be formed on one side of the now-expanding calice, while on the other side, no new ones will be produced, nor indeed needed, the old ones being still in actual use. The contraction may, however, be, and it often is, just sufficient to leave vacant only those loculi which have been formed by the later developed septa, and then there will be the full number of cycles on one side, while on the other the primary septa only will be present.

As observed by Dana, rejuvenescence is not of generic importance, and he might have said that it had no specific value, in which respect it differs widely from gemmation, which has not only specific but great generic value.

The Madreporaria of the Trias are very little known in this country, and beyond a few species which occur in the Sutton Stone of the Glamorganshire coast, we have to refer chiefly to Laube's descriptions and figures of the St. Cassian species. An examination of the compound genus *Elysastræa* reveals a very curious septal arrangement. This I will now proceed to consider, and it will be desirable that I should, in the first place, quote from Laube some part of his generic description. He says that gemmation takes place within the calice, and resembles that of *Heliastræa*.[1] He then goes on to state that the young individual separates itself by a little

[1] MM. Milne Edwards and Haime define the budding in *Heliastræa* in the following words: "Les nouveaux individus produits par bourgèonnement se montrent dans les differents espaces intercalicinaux." Probably gemmation in *Elysastræa* also took place in the intercalicular spaces.

wall by which the calice acquires the appearance as if a double wall were present, as in the Palæozoic genus *Acervularia*. By degrees the margin extends itself, until it blends with the thick surrounding margin of the older calice. Laube's figure illustrates the process above described. But both description and figures will apply with greater accuracy to rejuvenescence than to calicinal budding, which process in *Acervularia*, to which that of *Elysastræa* has been likened by Laube, is a process of multiplication, and in neither his description nor in the figure is there the slightest indication of an increase in the number of the corallites by calicinal budding. On the contrary, there are many small calices appearing amongst the larger ones, just as they would appear were they the result of marginal instead of calicinal gemmation.

Prof. Duncan, in describing the South Wales *Elysastrææ*, says that the budding is extracalicular, but that the bud probably has its origin in the centre of a corallite. No evidence is however adduced in favour of the latter supposition. None of my specimens from the Sutton Stone exhibit the budding process as it is shown in Prof. Duncan's figures, *i.e.* between the corallites; but they have rejuvenescence just as in Laube's figure. The young calices between the old ones in Prof. Duncan's figures are just such as would proceed from marginal gemmation in a genus in which the corallites are imperfectly united by their walls, and I have little doubt but that gemmation in *Elysastræa* is marginal, as it is in the so-called Liassic *Isastrææ*.

The nature of the endotheca in the South Wales *Elysastrææ* is very apparent and closely resembles that of the forms which I now bring together under the name of *Heterastræa*, in all of which, I may here observe, it is so very similar, that I do not find that it affords even so much as a specific difference. Vertical sections show how very similar it is in the several species.

There are some of the species which have occasional calices which are almost as free on the calicular surface of the corallum as those of *Elysastræa*. *Isastræa Murchisoni* is one of these, and, as mentioned by Prof. Duncan, some of the corallites are so much elevated above the others that there is "a faint trace of a subsequent growth of wall," by which I presume it is meant that there is an addition made to the wall after it has been formed. As will be hereafter mentioned when speaking of the species, there is also rejuvenescence in *Isastræa Murchisoni*, as there is in *Elysastræa*.

Bearing in mind all the foregoing considerations, I have arrived at the conclusion that there is a rather near relationship between the Triassic genus *Elysastræa* and the so-called Liassic *Isastræa* and *Septastræa*, and that the latter are one and the same generically, and quite distinct from the later Secondary *Isastrææ* and the Tertiary *Septastrææ*. The genus into which I now propose to place the following species, I name and define as follows:—

HETERASTRÆA, nov. gen.

The corallum is composite and massive, and the corallites are

united by their walls, but the union is often incomplete, and the line of contact frequently visible.

There is an occasional trace of a common or basal wall, with a rudimentary pellicular epitheca, both of which, however, are very often wanting.

The endotheca consists of dissepiments which are not vesicular, but flat and more or less tabular, and there are occasionally distinct tabulæ, many of them passing quite across from wall to wall of the corallite, forming a level floor to the calice.

Increase takes place by gemmation, which is strictly marginal, and never calicinal, and by fissiparity, which is first indicated by the elongation of the dividing calices, followed by the appearance of two or more fossulæ, which are finally divided from each other by the union of two elongated septa.[1]

The prevalence of gemmation over fissiparity, or the reverse, exercises a decided influence, not only over the shape of the calices, but also to some extent over the general contour of the corallum. The elevation of budding calices above the level of the surrounding ones tends to produce a more gibbous surface than does the division of the calices by fission, and the conformation of the corallum is modified accordingly. This will be further noticed when I speak of the species, which I shall now proceed to do, first enumerating those which I have not had the opportunity of examining. They are:—*Isastræa intermedia*, De Ferry; *I. excavata*, De Ferry; *I. basaltiformis*, Fromentel; *I. Orbignyi*, Chap. et Dewal.; *I. Condeana*, Chap. et Dewal.; *I. Moreneyana*, Terq. et Piette; *I.? Henacquei*, Ed. et Haime; and *Latimæandra denticulata*, Duncan, all of which have been stated to occur in the Lower Lias.

Heterastræa Murchisoni, Wright sp.

Isastræa Murchisoni, Dunc., Supp. Brit. Foss. Cor. pt. iv. p. 41, pl. xi. figs. 1–4.

The only example of this remarkable species, from the Isle of Skye, to which I have access, is small in size, and has but little calicular surface. Yet, small as it is, it has marginal gemmation, and elongated calices which, having more than one fossula, with an indication of dividing septa between them, affords indubitable evidence of fissiparity. Prof. Duncan says, "There is often a ridge between the margin of the calice and the centre, indicating calicinal gemmation, but the gemmation usually takes place at the margin, and there is no fissiparity." The ridge here mentioned has nothing to do with gemmation, but is merely the commencement of rejuvenescence, and in one calice of my specimen it has proceeded so far as

[1] It is necessary to notice here a variation in the process of splitting that takes place in different calices, or even in the same calice. The two opposite and approaching septa do not always meet and make the division until a new calice has been actually formed, and it is common for two or three fossulæ to make their appearance in a long calice with only some, or even without any, dividing septa. When this is the case, there is some resemblance to *Latimæandra*. However, the septa always become elongated sooner or later, and fissiparity is then complete. M. de Fromentel gives a good account of the process in his description of the so-called *Septastræa excavata*.

to have given rise to a smaller calice within the larger one, which has a considerable degree of prominence, and bears an extremely close resemblance to some of the corallites represented in the upper part of Laube's figure of *Elysastræa Fischeri*.

I have met with two ill-preserved specimens of a coral which resembles this species in the size and openness of the calices, the one from a gravel-pit at Charlton, near Evesham, and the other from the zone of *Ammonites angulatus*, near the village of Church Lench, a few miles north-west of Evesham.

HETERASTRÆA EVESHAMI, Dunc. sp. Pl. VII. Fig. 3.

Septastræa Eveshami, Dunc., Supp. Brit. Foss. Cor. pt. iv. p. 52, pl. xiii. figs. 5–7.

By the kindness of my friend the Rev. P. B. Brodie, the type-specimen of this species is now before me. The calices, which are in process of division, or have already undergone that operation, are conspicuous over the whole upper surface of the corallum, but gemmation, though apparent and marginal, is not frequent; nor is it common, though well marked, in other specimens of this species in my collection.

It is a distinct species, and in some examples the specific characters are even more typically developed than in the type itself. They are all more or less flabelliform, but they present every degree of inclination from a nearly vertical to a horizontal position. The finest specimen yet met with has the form of a regularly oval plate, ten inches long, and not more than an inch in thickness. It was attached by a broad space near one end of the under side, which is flat. The calicular surface is horizontal. Fissiparity occurs over the whole of the latter part, but gemmation is by no means common, though, where it appears, it is unmistakeable. This specimen was taken from a quarry near to Prior's Cleeve, about five miles north-east of Evesham, and its place in the Liassic beds will be best explained by the following section:—

		Ft.	Ins.
1	Surface soil with pebbles, about	2	0
2	Light-coloured clays	11	6
3	Black laminated shale with fragments of shells and Echinoderms, and a specimen of *Heterastræa Eveshami*	3	6
4	Indurated dark grey shale	0	3
5	Laminated stone with *Ammonites planorbis* and insect remains	0	6
6	Laminated shale	3	3
7	Laminated stone	0	7
8	Laminated shale, the upper and lower parts of which are light in colour, and the middle black. The latter is a mud deposit and contains the joints of *Pentacrinites*, *Cidaris* spines, and comminuted shells.	3	3
9	Laminated stone, with *Am. planorbis*	0	3
10	Laminated shale	0	7
11	Laminated stone	0	6
		26	2
12	Laminated shale, beneath which is the *Ostræa* bed, depth not ascertained.		

I have also obtained the present species from Binton, about four or five miles west of Stratford-on-Avon, where it was associated with *Ammonites angulatus*.

HETERASTRÆA FROMENTELI, Terq. et Piette sp. Pl. VII. Fig. 4.

Septastræa Fromenteli, Terq. et Piette, Lias Inf. de l'Est de la France, etc.
——— ———, Duncan, Supp. Brit. Foss. Corr. pt. iv. p. 37, pl. xi. fig. 5.

The example of a supposed *Septastræa* which was found in the railway cutting at Harbury, and mentioned by Prof. Duncan, as above, has been submitted to me by my friend Mr. Brodie, in whose collection it is, and a comparison has been made between it and other allied species. Two contiguous calices of this specimen are very remarkable, for on the margin of one there is gemmation, while the other is divided in half by the process of fissiparity. In no other species, or specimen, have I seen the two processes so closely associated or so obvious. Fissiparity is however much more frequent than gemmation in this specimen.

As I have only had the opportunity of examining English specimens of this species, my observations must be understood to apply to them exclusively, though I have no doubt that the French and English specimens are of one species.

HETERASTRÆA STRICKLANDI, Dunc., sp. Pl. VII. Fig. 8.

Isastræa Stricklandi, Dunc., Supp. Brit. Fos. Cor. pt. iv. p. 54, pl. viii. figs. 1-4.

The type-specimen of this species was obtained by Mr. Strickland from the clay-pit of the Chadbury brickyard, from which excavation a considerable number of specimens of so-called *Isastrææ* and *Septastrææ* were taken, some of which agree very closely with the description of this species by Prof. Duncan. I have not, however, been able to examine the type-specimen. It does not appear to be a very abundant species, only three having come into my hands. Two of them came also from the Chadbury clay-pit, and the other was dug up by a market gardener when trenching his land on the side of the hill north of Evesham on which the battle of Evesham was fought. This species is distinguished, as pointed out by the original describer, by its stout septa and thick walls. The calices are rather shallow. There is no instance in either of my specimens of budding actually taking place, though there are calices which from their circular form and their position amongst other calices have certainly proceeded from marginal budding. Fissiparity is common, and sometimes occurs rather peculiarly. The division of a calice takes place all round it, and a very large lobular calice is the consequence, and when the dividing septa make their appearance, they have a somewhat radiate arrangement.

HETERASTRÆA INSIGNIS, Dunc., sp.

Isastræa insignis, Dunc., Supp. Brit. Foss. Corr. pt. iv. p. 54, pl. xiii. figs. 10, 11.

The specimen on which Prof. Duncan established this species was obtained by me from the Lower Lias at Lyme Regis, but as the opportunity of making an examination of it since it has become a type has not occurred to me, I am compelled to fall back upon the other specimens from the same locality, of the specific identity of which, however, I entertain no doubt. Several similar specimens came into my hands with the one I lent to Prof. Duncan. These I

still have, and they have been referred to on the present occasion. They are without doubt referable to the same genus as the other species herein mentioned.

HETERASTRÆA ENDOTHECATA, Dunc. sp. Pl. VII. Fig. 9.

Isastræa endothecata, Duncan, Supp. Brit. Fos. Cor. pt. iv. p. 53, pl. xii. figs. 17-21.

Of this species the original describer says "the marginal gemmation is frequent." The figured specimen is now before me, and I observe a considerable number of calices which are elongated and have more than one fossula, as well as marginal gemmation, which is common. The irregularity in the size and form of the calices is due to the operation of these two processes proceeding at the same time. Besides the type-specimen, I have some others taken from the *Ammonites angulatus* beds of the Lower Lias, about a mile west of Evesham. These examples have a very distinct line where the corallites come together, indicating imperfect union.

HETERASTRÆA HAIMEI, Wright sp.

Septastræa Haimei, Duncan, Supp. Brit. Fos. Cor. pt. iv. p. 5, pl. i. figs. 1-5.

In 1860, when my late friend Dr. Wright was engaged in investigating the Ammonite zones of the Lower Lias, he obtained an *Isastræa* from the *Ammonites planorbis* beds of Street, and it was mentioned under the name of *Isastræa Murchisoni*, at pages 390 and 397 of the paper which followed his investigations. The specimen was for some time in my hands, and was afterwards described and figured by Prof. Duncan under the name of *Isastræa latimæandroidea*. At this time an *Isastræa*, said to have been obtained from Evesham, also formed part of Dr. Wright's Collection, but no mention was then made of it by him, though afterwards, in one of the volumes of the Palæontographical Society, it was mentioned as *Isastræa Haimei*, and as I then believed, and still believe, was erroneously stated to have been also obtained from the *Ammonites planorbis* beds of Street. Instead, however, of its appertaining to that Ammonite zone, I entertain no doubt whatever that it is referable to the *Ammonites angulatus* beds of the neighbourhood of Evesham.

Prof. Duncan subsequently described and figured it as *Isastræa Haimei*. As I have not recently had the opportunity of examining the type-specimen, I cannot speak decisively of its generic relationship, though I do not doubt that it is a species of *Heterastræa*.

HETERASTRÆA TOMESI, Duncan sp. Pl. VII. Figs. 5, 6.

Isastræa Tomesi, Duncan, Supp. Brit. Fos. Cor. pt. iv. p. 46, pl. xv. fig. 20.

The type of this species is so indifferently preserved that were it not a well-marked species it would be practically useless for comparison. But the very thin walls and septa which are apparent, whatever may be the condition of the specimen, will at once distinguish it. As a species it is not by any means uncommon; and I have seen specimens from several localities in the neighbourhood of Evesham, in addition to Grafton, where the type was obtained. It

is a low expanding form, sometimes attaining to a great size. The largest I have yet seen is almost as heavy as a man can lift. On nearly every part of this massive specimen the line where the corallites come into contact with each other is very visible, and in some places there appears to be a slight but perceptible interval between the walls. Marginal budding is frequent, and fissiparous division of the calices is observable everywhere. Some of the calices are more than an inch in length, and have a very remarkable and almost serpentine form, with four or five fossulæ, the long dividing septa being present between some of them, but not between others. At one place rejuvenescence occurs in several contiguous calices, and they appear as double, or one within the other, just as they appear in the upper part of Laube's figure of *Elysastræa*, and here and there a corallite, near the outside of the corallum, is elevated above the rest and there is a trace of an after-growth of epitheca.

HETERASTRÆA LATIMÆANDROIDEA, Dunc. sp.

Isastræa latimæandroidea, Duncan, Supp. Brit. Fos. Cor. pt. iv. p. 65, pl. xxv. figs. 18, 19.

The specimen of this species, which was obtained by Dr. Wright from the *Ammonites planorbis* bed of Street, was for some time in my hands, and a facsimile in plaster, taken by means of a wax impression, is now before me. Marginal gemmation is obviously very abundant, and the elongated calices having more than one fossula, are indicative of fissiparity. The specimen is only a fragment and its specific independence is very doubtful.

HETERASTRÆA ? SINEMURIENSIS, From. sp.

Isastræa sinemuriensis, E. de From. in Martin, Pal. Strat. de l'Infra Lias, Cote d'Or.
Isastræa sinemuriensis, Duncan, Supp. Brit. Foss. Cor. pt. iv, p. 30, pl. vii. figs. 1-9.

If the Brocastle specimens are rightly identified with this species, then it, like so many other of the so-called *Isastrææ* of the Lias, increases by marginal instead of calicinal gemmation. This is evident in my specimen, and it has also been figured by Prof. Duncan (Supp. Brit. Foss. Cor. as above) from specimens in the collection of the late Mr. Charles Moore.

Of *Isastræa gibbosa* from the same locality I can only say that in the specimens I have examined there was no evidence of any process of increase.

HETERASTRÆA EXCAVATA, Fromentel, sp.

Septastræa excavata, E. de From. in Martin, Infra Lias, Cote d'Or. 1860.

Two specimens of a Coral which I refer to this species have come into my hands, both of which were taken from the low-lying gravel at Charlton, about a mile north-west of Evesham. They resemble each other in having a regularly oval form, and are somewhat depressed, though they have an evenly convex calicular surface. A larger example than either of these would, if broken up, furnish precisely such fragments as the one figured by M. de Fromentel. In all the details of the form, size, and arrangement of the corallites and their calices, as well as the development of the septa, my

specimens are fully in accord with the fragment figured by M. de Fromentel, excepting that in addition to fissiparity there is undoubted marginal gemmation, which is, however, unfrequent, not more than three or four instances appearing on either specimen.

HETERASTRÆA ETHERIDGEI, sp. nov. Pl. VII. Figs. 1, 2.

This species, which appears to be undescribed, bears a little resemblance in the form of the corallum to *H. Haimei*, but it differs greatly in the size of the calices, which are scarcely half the size of those of the last-named species.

The corallum is tall and somewhat compressed, with a rounded top, the whole surface being closely covered with calices, which are hexagonal, shallow, and saucer-shaped. The walls are thick, but when entire come to a sharp well-defined edge, and there is a very distinct though fine line where the corallites come together, indicating imperfect union.

No cyclical numeration of the septa can be formulated. There are about twenty-four in a medium-sized and regular calice, and nearly half of them pass almost into the centre of the calice, but do not quite meet. In the elongated calices, however, the longest from the opposite sides meet in the middle line. The others are too irregular to be determined. All the septa are of medium thickness, which they maintain as they pass inwards. In an unworn calice they all have margins which are regularly tuberculated, about eight to ten prominent tubercles being observable on the longer ones.

The tallest specimen I have seen measures four inches in height, and has a diameter of about two inches. Diameter of the calices from one and a half to two lines.

Gemmation and fissiparity occur quite freely and with about equal frequency on all parts of the corallum.

I have examined several specimens from the Lower Lias of the East Cliff, Lyme Regis, and I possess one which was taken from the gravel-pit at Charlton, near Evesham.

HETERASTRÆA REGULARIS, sp. nov. Pl. VII. Fig. 7.

The corallum of all the specimens I have seen was attached by a small oblong space, from which it expanded rapidly, and was surmounted by an irregular overhanging flattened or rounded top, with some elevated lines and gibbosities. The corallites are rather small and angular, and, generally speaking, hexagonal, and their union with each other is indicated by a fine but very distinct line. The calices are deep, almost as deep as wide, and the walls are regular, thin, upright, and straight between the angles. The septa are rather regular, straight, and rather thick, and they hold their thickness quite into the centre of the calice. There are six systems, and three cycles and a rudimentary fourth. The septal edges have large rounded denticulations, which are few in number and lobular. The primary septa are six, and they unite in the centre of the calice and form a false columella, which, however, is not very apparent until the tabulæ forming the floor of the calice have been broken through.

Those of the second cycle are two-thirds the length of the first, and those of the third two-thirds the length of those of the second, while the septa of the fourth cycle are merely rudimentary.

Marginal gemmation and fissiparity both occur, but are not frequent.

This species may be readily distinguished from all the others by the small number and the regularity of the septa, the cycles of which can readily be determined in a fairly symmetrical calice. In the larger and more irregular ones, however, the septa are a little more numerous, and the cycles cannot be traced. Another distinction consists in the union of the primary septa low down below the calice, and thus forming a false columella, which becomes conspicuous when the dissepimental floor of the calice has been destroyed and the septa worn down. I have not seen this in any other species.

The most regular calices have a diameter of about two lines, but the larger and more irregular ones are nearly three lines in breadth.

Two examples have been obtained from the *Ammonites angulatus* beds in a field called "Salmon's Stile," near the village of Littleton, north-east of Evesham, and another from near the village of Cropthorne, west of Evesham.

HETERASTRÆA BINTONENSIS, sp. nov.

There is a large and nearly globular species having a very gibbous upper surface, and rather small calices with thick walls, which I have at present been unable to refer to any known species. It occurs in the *Ammonites angulatus* beds at Binton Hill, four miles west of Stratford-on-Avon, and at Down Hatherley, Gloucestershire, where my friend Mr. Brodie found a specimen, and kindly forwarded it to me for my use on the present occasion. Other specimens have been taken from the Charlton gravel-pit.

The calices are rather small, and are mostly hexagonal, but they have a rounded appearance, owing to the walls being thickened just at the angles. They are very seldom elongated. The septa are straight, thin, and in the larger calices there are from forty to forty-six. About nine or ten are longer than the others, but do not meet in the centre of the calice, there being an open fossula of nearly one-fourth of the diameter of the corallite, which is only closed by the tabular dissepiments. A corresponding number of septa are about half or two-thirds the length of the long ones, and all the others are too short and variable to be enumerated.

Gemmation occurs rather freely, but fissiparity is much less common.

The diameter of a large specimen is about six inches, of a smaller one three or four inches. The calices are from two to two and a half lines wide.

The thick walls, the more or less rounded form of the calices, and the open fossula will distinguish this species, and I may add that all the specimens I have seen have had a more or less globular form.

HETERASTRÆA sp.

I have before me several specimens of a species which is

obviously quite distinct from any of the foregoing, but which are not sufficiently well preserved to admit of description. They consist of thin plates, from half to three-fourths of an inch in thickness, which had nearly an upright position, and have calices, all of which are oblique. They were found in the neighbourhood of Evesham.

DESCRIPTION OF PLATE VII.

FIG. 1. *Heterastræa Etheridgei*, a horizontal section a little below the calice, showing the imperfect union of the corallites, fissiparity in progress in two corallites, and one corallite which has resulted from gemmation. Magnified three diameters.

„ 2. „ *Etheridgei*, a vertical section showing the dissepiments and the edges of the septa. Magnified three diameters.

„ 3. „ *Eveshami*, a portion of the type specimen showing a calice which has been developed from a bud, and still retains a more or less circular outline. Magnified two diameters.

„ 4. „ *Fromenteli*, a portion of the specimen figured by Prof. Duncan, exhibiting, in close proximity, both gemmation and fissiparity. Magnified two diameters.

„ 5 & 6. „ *Tomesi*, portions having calices resulting from both gemmation and fissiparous division. Magnified two diameters.

„ 7. „ *regularis*, some calices magnified two diameters.

„ 8. „ *Stricklandi*, some calices of a specimen from Evesham, having both gemmation and fissiparous division. Magnified two diameters.

„ 9. „ *endothecata*, a portion of the type specimen, showing fissiparous division in progress. Magnified two diameters.

III.—On Some Effects of Pressure on the Devonian Sedimentary Rocks of North Devon.[1]

By J. E. Marr, M.A., F.G.S.

DURING Professor Hughes' annual geological excursion, which was last Easter conducted to Ilfracombe, I was much struck with certain structures exhibited by the ordinary Devonian sediments, and some of these are, I think, worthy of a short notice. Most of them are exhibited on the beach close to Ilfracombe, at the bathing place, where there is also seen the folded grit band rendered classical through Dr. Sorby's writings.

The rocks here consist of cleaved argillaceous deposits interstratified with thin grits and limestones, and the latter have been folded amongst the former in a most remarkable manner. The changes which take place are illustrated in Fig. 1. The first stage is the production of a series of sigmoidal folds having the middle limb replaced by a thrust-plane. This is well shown in the case of two limestone bands just above a small cave on the shore, at the bathing place. A further development is shown in Fig. 1*a*, and the result of this is the formation of a series of "eyes" of limestone, which vary in length from a fraction of an inch to several feet, according to the magnitude of the folds. As the smaller folds are merely the convoluted portions of larger ones, the "eyes" get pulled out along the thrust-planes, replacing the middle limbs of the larger folds, as shown in Fig. 1*b*. In this way, the central portions of these larger folds

[1] Read at the Manchester Meeting of the British Association.

present the appearance shown in Fig. 1*c*, where we find a series of lengthened "eyes," forming flattened lenticular patches interbanded with the normal cleaved argillaceous material. By these simple changes we have produced a rock having all the mechanical characters of a schist, but consisting of alternating lenticular patches of limestone and clay-slate, and presenting the apparent false-bedding which is also seen in true schists. The apparent dip of the rocks is here entirely fallacious, and is due to the pulling out of the limestone "eyes," so as to have their longer axes parallel with the general strike of the cleavage planes. In many cases the cores of the larger folds have the "eyes" compressed together to form an irregular nodular mass, in which the separate "eyes" can be some-

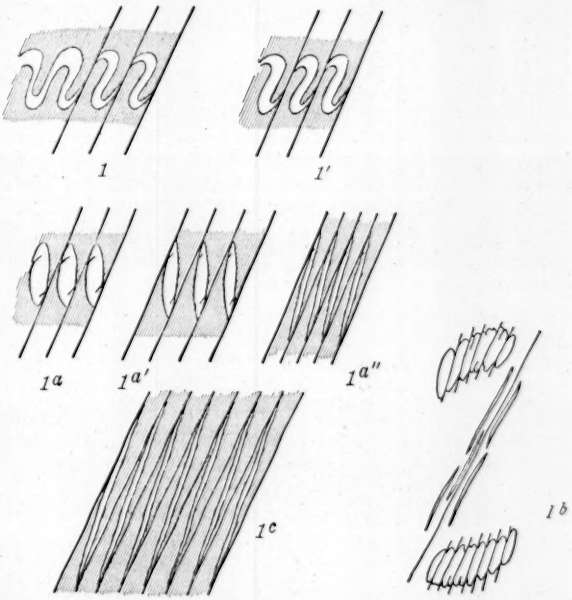


Fig. 1 1′. Transition from ordinary overfolds to the stage 1*a*.
,, 1*a*. As in text.
,, 1*a*′ 1*a*″. Transition from 1*a* to 1*c* as produced along the fault plane in 1*b*.
,, 1*b* 1*c*. As in text.

times with difficulty determined, but at other times the lines of demarcation are wholly obliterated. In these masses, the crinoid joints of which the limestones are largely composed are affected in the way described by Dr. Sorby in his Presidential Address to the Geological Society (Q.J.G.S. vol. xxxv. p. 89), and in some cases are seen converted into a number of irregular polygons. Along the planes where the limestone "eyes" have been dragged out, we find that the crinoid stems are separated in a way similar to that figured by Heim in the case of a Belemnite (Mechanismus der Gebirgsbildung, pl. xv. fig. 6), and the spaces separating the different joints are then filled with crystalline calcite.

The changes occurring in the case of the thin grit bands are generally similar to those described above; but here we find also that the particles are compressed, and there appears to have been a slight mineral rearrangement. The grits are nevertheless easily distinguishable as such even to the naked eye.

The rocks at the bathing place are furthermore traversed by quartz veins, some of which were formed before the principal folding of the rocks, and in this case, the veins are affected in the same way as the thin bands of limestone. Fig. 2 shows the foldings of such a quartz vein, as seen close to the Tunnels at the

Fig. 2.

bathing place. Here two quartz veins occur parallel with two thin bands of limestone, and are folded like the limestone, showing that the veins were formed along the bedding planes, before the latter were affected by the folding. At this spot, both limestone and folded quartz veins suddenly disappear against a large divisional plane to the right, and a few feet to the right of this plane a series of quartz veins run parallel with the cleavage planes. It is possible that the latter veins were produced by the mechanical rearrangement of the folded veins along the thrust plane of a large fold, but it is not easy to prove this, as in the case of the limestones, and the rectilinear veins may have been formed in their present condition by segregation. Upon a flat surface of rock to the south of this place, quartz veins are seen formed into "eyes," and these "eyes" in places have been almost certainly dragged out. In such cases we have the incipient formation of a schistose rock composed of alternating lenticular masses of argillaceous material, limestone and quartz. Precisely similar phenomena may be seen at Hagginton Beach and elsewhere, and indeed the whole coast offers excellent examples of the formation of these schistose structures in ordinary sediments, where all the mechanical peculiarities of a true schist are visible, without any great change in the chemical composition of the individual constituents of the rock.

At Hagginton Beach a mass of limestone occurs, which has been pulled out so as to form a series of elliptical nodules occurring in the same line. Here we find the junction of limestone "eyes" without any folding of the particular mass of limestone in which the "eyes" occur. A flattening of these "eyes" would cause the formation of lenticular masses of limestone of a similar character to those described as occurring at the bathing place; nevertheless the mode of formation of the "eyes" is quite different in the two cases.

Some of the smaller "eyes" seen in a cliff just north of Hagginton Beach are composed of masses of coral. The elliptical shape of the

"eyes" does not appear to be due to the original growth of the coral, for the sides of the nodules are seen to consist of sections of the coral. This may be owing to chemical solution of some parts of the limestone, but appeared to me to be caused by the actual shearing off of a portion of the coral. This supposition requires confirmation, and it is probable that a fuller examination of the district will yield the requisite evidence.

The structures seen in these North Devon rocks remind one of those described by Dr. Bonney as occurring at Tor Cross in S. Devon (Q.J.G.S. vol. xl. p. 1). He brings forward proof to show that in that region "there is no valid evidence of a passage from schist to slate." The occurrence of rocks in North Devon having all the mechanical structures of true schists, without possessing their peculiar chemical composition, bears out this conclusion. In connection with this, it is of interest to notice that whereas in South Devon, where phyllites are found associated with normal schists, the sedimentary rocks are largely penetrated by igneous intrusions, this is not the case in North Devon, where such intrusions are very rare. One mass of quartz felsite, which has been described by Dr. Bonney (Geol. Mag. 1878, p. 207), does occur at Bittadon, and he states that it is "affected slightly by cleavage." It was therefore intruded prior to the last earth-movements of this area. In some parts of the rock there is a parallelism of the alteration products which have been developed along the line of cleavage, but unfortunately the portion of the rock which has undergone the greatest amount of cleavage is so decomposed that no specimen could be obtained sufficiently firm for slicing. The apparent absence of schistosity in this rock can be however accounted for on the supposition that at the place where it is exposed, the mass forms an "eye" which has not undergone any great change. It would be of interest to know if this rock is exposed elsewhere, and if so, under what conditions it is there found.

I am indebted to Mr. E. J. Garwood, B.A., F.G.S., for the use of photographs displaying many of the structures which I have described above.

IV.—Notes on the Geology of Mynydd Mawr and the Nantlle Valley.

By Alfred Harker, M.A., F.G.S.,
Fellow of St. John's College, Cambridge.

Mynydd Mawr, about three miles west of Snowdon, is an abrupt rounded hill, 2300 feet high, separating the valleys of Nantlle and Cwellyn. A reference to the maps of the Geological Survey (75 N.E. and N.W.) shows it to be due to an isolated boss of "intrusive hornblende-porphyry" in the form of a rounded parallelogram, a mile and a half in its longest diagonal. Dr. Hicks[1] has mapped this patch as Pre-Cambrian, and included it in his Arvonian system; but apart from its position, breaking

[1] Q.J.G.S. vol. xxxv. p. 297, 1879.

through a regular succession of Cambrian (or Ordovician) rocks, an examination of the junction affords convincing proof of its intrusive character. On the northern flanks of the hill the relations are well exhibited, and the induration and extensive mineralogical alteration of the slate in the vicinity of the boss are very marked. It is indeed by no means easy to determine on the ground the precise point where the hardened, semicrystalline slate gives place to the porphyry.

The question may, however, be approached on a different line, which indicates a higher, as well as a lower, limit to the age of the intrusion. A series of observations with compass and clinometer may, I believe, be made to yield interesting results in many districts of cleaved rocks, and so no apology seems needed for introducing in this connection a few remarks on the arrangement of the cleavage-planes in the slaty rocks of the Vale of Nantlle.

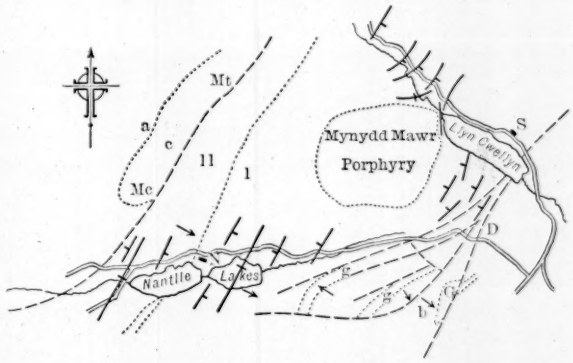
All the peculiarities of slaty cleavage may be studied to advantage in the slate-quarries of the lower part of the valley, which are worked in Lower Cambrian rocks resembling those of Llanberis. Here, as usual, a great perfection of the cleavage-structure is found associated with high angles of cleavage-dip. The cleavage-strike seldom deviates more than a few degrees from N. 36° E.—S. 36° W., which is also about the *normal* strike of the strata, in accordance with the law developed by Sedgwick, Darwin, Jukes, and others. It also agrees nearly with the trend of the great Archæan ridge, which extends from Llanllyfni to beyond Llanberis. The quartz-porphyry composing this ridge has itself been structurally affected by the same stress which originated the cleavage of the neighbouring slates. The platy structure of the mass, well seen at Cilgwyn, Pen-y-groes, etc., has the same strike; it is not mere jointing, but is often seen to be in direct relation with a certain schistosity of the quartz-porphyry.

The variations of cleavage-dip in the Nantlle slates agree well with the rules laid down by Sharpe forty years ago. A little west of the lower lake runs a line of vertical cleavage, nearly coinciding with the bye-road from Tal-y-sarn to Llanllyfni. On each side of this line of strike the cleavage-planes dip away from it at high angles, so that the cleavage-dip in the Pen-y-bryn and other quarries near Nantlle itself (Nant-y-llef on the maps) is south-easterly. Another line of vertical cleavage passes through the middle of the upper lake, and in the slates on each side of this the cleavage-planes dip in towards this line. The north-westerly cleavage-dips hold up the valley with a gradually decreasing angle, to 56° at Drws-y-coed Pass. The strike of the cleavage remains very constant in these higher beds, although the strata themselves in the neighbourhood of the Tal-y-mignedd copper-lodes change their bearing considerably, curving round towards the east. This is an example of the law that the cleavage of a district, while following the trend of the main axes of disturbance, is independent of minor variations in the strike of the strata. Occasionally local irregularities occur, which are clearly traceable to subsequent faulting. It is noticeable that, with

decreasing angles of cleavage-dip, the cleavage-structure becomes less perfect, and the rocks cease to be worth working for slates.

A similar regularity may be traced in the cleavage of the rocks in the Cwellyn Valley on the north side of Mynydd Mawr, the average strike being towards N. 30° E., with small deviations, and the dip of the planes varying gradually as before. In the neighbourhood of the hill itself, however, the case is different. Considerable deviations present themselves, and these are found to follow a definite law: in brief, the cleavage-strike becomes more and more changed

Sketch-Map of Mynydd Mawr District.



Scale: One inch to two miles.

S, 'Snowdon Ranger;' D, Drws-y-coed; G, Y Garn; N, Nantlle; Mc, Mynydd Cilgwyn; Mt, Moel-y-Tryfaen: *a*, Archæan ridge; *c*, Cambrian basement conglomerate; *ll*, Slates of Nantlle quarries = Llanberis series; *l*, Higher slates = Lingula flags and newer beds; *g*, Grits of Tal-y-mignedd (? Arenig age); *b*, Slates of Bala stage.

— — — Faults; ↘ Dip of strata; —+— Strike and dip of cleavage; —+— Vertical cleavage.

as we approach the porphyry, *tending always towards parallelism with the boundary of the intrusive mass.* For instance, on the north side the cleavage-strike becomes deviated so as to bear always more easterly, as far as N. 70° E. and even N. 85° E., with increasingly high dips towards the south-east and south. This variation cannot be traced so far as the actual junction, for the rock there is so indurated that it has been able to resist the mechanical stress. On the east side of the hill, on the other hand, the cleavage-strike is deviated towards the north, and in the narrow strip of slates where the lake approaches most closely to the porphyry, the cleavage bears due N.—S., with a dip of 83° to the west. Doubtless, if we could lay bare the whole tract, the cleavage-strike would be seen curving round the mass of porphyry, just as the lines of flow in a rhyolite curve round a porphyritic crystal, or as the fibres of wood are deflected by a knot.

The only explanation of the peculiarities just described is that, when the whole district was operated upon by the powerful lateral pressure which produced the cleavage-structure, the unyielding mass

of porphyry interposed a hard obstacle; in its neighbourhood, therefore, the resultant compression tended to be perpendicular to the boundary of this obstacle, and so the cleavage-surfaces produced tended to be parallel to the boundary. A little consideration will show that such great deviations could not be brought about by disturbance due to the intrusion of the porphyry *after* the impression of the cleavage-structure. Moreover, in such a case, the cleavage-planes, owing to their very high angles of dip, would have been less affected as regards strike than the strata. The bedding is in fact disturbed near the junction, but no great changes in its direction of strike are to be noticed. Again, we have seen that the cleavage-planes on the north side of the hill dip towards it, and the angle of dip increases on approaching the porphyry, until vertical. If the intrusion had disturbed the rocks after they had become cleaved, the reverse should be the case.

It appears certain then that the porphyry of Mynydd Mawr is truly intrusive; that it is newer than the surrounding rocks, but older than their cleavage. The rocks in question are probably Arenig, though possibly older, their age, in the absence of fossils, being necessarily in doubt (Ramsay, Geol. N. Wales, 2nd ed. p. 168). The era of the cleavage is, according to all the evidence obtainable, the close of the Cambrian period of Sedgwick, or at least, as Sir A. Ramsay puts it, "before the commencement of the deposition of the Upper Llandovery strata" (*ibid.* p. 326). The intrusion of Mynydd Mawr, then, may well be of Bala age. Ramsay remarks that the summit of Y Garn, about two miles south of Llyn Cwellyn, which is mapped as "greenstone," consists of an igneous rock similar to that of Mynydd Mawr, and the slates on its western side, which form part of the Bala stage, are seen to dip under the rock in question. The vertical cleavage of the slates near the junction of the Mynydd Mawr mass indicates that the boundary of the latter is nearly perpendicular. It seems very probable then that this great boss of porphyry is the plug of a volcanic vent of Bala age, and may mark the source of some of the lavas of Snowdon, Moel Hebog, and Llwyd Mawr.

If this be so, a petrological examination of the Mynydd Mawr rock will have a special interest. Without attempting a complete description of it, its chief characters may be briefly noted. The rock is unique in appearance and easily recognized when met with in the drift of Moel Tryfaen and Nantlle. To the eye it appears as a bluish-grey compact mass, pinkish or cream-coloured when weathered, in which are imbedded imperfect linear crystals of a lustrous black, arranged in parallel streams. The general characters are very constant throughout the whole extent of the hill: the black crystals, however, usually about a quarter of an inch in length, sometimes attain a larger size; felspar crystals are often visible, and scattered grains of quartz. The mass exhibits a platy jointing, sometimes in two intersecting directions, and about Craig-cwm-bychan the columnar structure is often very marked.

Sir A. Ramsay (*op. cit.* p. 171) refers to the black crystals as

hornblende, but in the late Mr. E. B. Tawney's copy of the memoir this is altered in the margin to "tourmaline." An examination of several thin sections of the rock reveals always both minerals in close association and in about equal quantities.

The microscope shows a fine-grained ground-mass, enclosing, besides the hornblende and tourmaline, porphyritic felspars and sometimes crystalline grains of quartz. Some of the black crystals of the hand-specimens are seen to be hornblende, some tourmaline, while others consist of both minerals closely associated, with a very irregular or ragged line of junction. The boundaries of the crystals show no idiomorphic outline, but an extremely ragged edge, owing to their including granules of quartz and felspar similar to those of the ground-mass. Most of the crystals, too, both hornblende and tourmaline, contain these granules throughout their interior, so that the sections, instead of being solid, have a porous or spongy appearance.

The tourmaline is of the blue variety of that mineral, and the absorption, for both ordinary and extraordinary rays, is so complete that slices of the usual thickness are almost opaque, giving in their thinnest portions a deep indigo-blue tint. No traces of cleavage are apparent.

The hornblende has the usual prismatic cleavage well marked. It is remarkable chiefly for its abnormal colours and intense dichroism. Vibrations parallel to the a-axis of elasticity give a rather light brown colour, those parallel to β and γ a very deep blue, having perhaps a greenish tinge in the former case and indigo in the latter, but the absorption is so strong that the crystals appear almost opaque when the a-axis is approximately perpendicular to the shorter diagonal of the Nicols prism. This deep tint is indistinguishable from that of the tourmaline in the same slides.

The porphyritic felspars present square sections, twinned apparently on the Carlsbad model. They may be orthoclase, but are too much destroyed to allow of identification. These crystals are of earlier consolidation than the hornblende and tourmaline.

The ground-mass is a finely granular admixture of quartz and orthoclase, as in an ordinary "micro-granite," but containing in addition another mineral which is often plentiful. It occurs in minute crystals, of acicular or rectangular form, scattered through the ground-mass or included by the other constituents, and having usually a fluxional arrangement agreeing with that of the parallel hornblende and tourmaline streams. The mineral is colourless, or in the larger crystals gives for vibrations parallel to the long axis a faint tint of indigo-blue. The crystals give high polarisation colours and straight, or nearly straight, extinction. They have a high refractive index, which causes them to stand out in relief when viewed by ordinary transmitted light. They may perhaps be another generation of tourmaline.

These acicular crystals evidently belong to an early stage of the solidification of the magma, and it is important to notice that their disposition agrees with the fluxional arrangement of the visible

black crystals, which must have consolidated almost at the same time as the granular ground-mass. The structure of the rock seems not incompatible with the idea that it was formed in the pipe of a dying volcano, when the upward flow became gradually arrested and the remaining magma slowly solidified into a plug under the pressure of the superincumbent column. Tourmaline, though not a constituent of true lavas, is by no means unknown in the quartz-porphyries of some other districts: the blue variety occurs, for instance, in the Harz Mountains.

P.S.—With reference to the discovery of glaucophane in Anglesey, announced by Prof. Blake in the March Number of this Magazine, it may be noted that the blue amphibole of the Mynydd Mawr rock differs from that mineral in the character of its absorption and pleochroism, as well as in the absence of crystal form and of the peculiar "cross-jointing." Glaucophane has not, I believe, been recorded from non-metamorphic igneous rocks. A good *résumé* of the literature relating to this mineral has recently been given by Oebbeke.[1]

V.—Note on the Spicules described by Billings in Connection with the Structure of *Archæocyathus Minganensis*.

By George Jennings Hinde, Ph.D., F.G.S.

In "The Palæozoic Fossils of Canada," vol. i. p. 3, the late Mr. Billings stated that by treating a silicified specimen of *Archæocyathus Minganensis* with acid, he ascertained that it contained numerous siliceous spicula—slender, fusiform, slightly curved, acute at both extremities—and that these fossils must therefore be classified among the extinct tribes of sponges. Referring again to this species in the latter part of the same volume (pp. 354–357), this author states that he had found the same spicula present in great numbers in another large species, *Trichospongia sericea*, and that it therefore remained an open question whether they actually form part of the structure of *Archæocyathus*, or belonged to *Trichospongia*. In addition, however, to these simple detached spicules, Mr. Billings describes and figures (*loc. cit.* p. 355, fig. 344) "branching spicula," which "are seen imbedded in, and forming a part of, the substance of the outer wall of *A. Minganensis*." No doubt could be entertained that these so-termed branching spicula really belonged to the fossil, since they could "be seen, not only projecting from the surface of the silicified specimens, but also in the thin slices prepared for the microscope."

Since the description of *Archæocyathus* by Mr. Billings appeared, the nature of this fossil has been investigated and referred to by several eminent palæontologists, amongst whom may be mentioned,

[1] See Ueber den Glaukophan und seine Verbreitung in Gesteinen, von Herrn K. Oebbeke, Zeitsch. der deutschen Geologischen Gesellschaft, 1886, vol. 38, p. 634.

Meek,[1] Dawson,[2] Ferd. Rœmer,[3] Börnemann,[4] Walcott,[5] and Schlüter,[6] but it cannot as yet be said that any satisfactory or decisive conclusion as to its character and affinities has been arrived at. Mr. Billings's statement as to its spicular structure has considerably increased the perplexity of the subject and influenced opinion in favour of its alliance[7] to sponges; any fresh information therefore respecting the nature of these spicules and their relation to the fossil *Archæocyathus*, may help to remove an element of uncertainty in the consideration of the question as to its true nature.

Fig. 1.

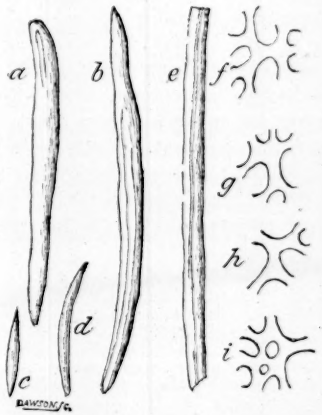


Fig. 1. Detached spicules of siliceous sponges occurring in specimens of *Archæocyathus Minganensis*, Billings, and the so-termed branching spicula of the same fossil. *a*, Acuate spicule, showing traces of the axial canal. *b*, *c*, *d*, Different forms of acerate spicules; in (*b*) the axial canal is partially preserved. *e*, Fragment of a cylindrical spicule showing the axial canal. All enlarged to the same scale of 40 diameters. *f*, *g*, *h*, *i*, Silicified fragments of the outer wall of *A. Minganensis*, the so-called "branching spicula" of Billings. Reduced from Billings to the scale of 40 diameters.

Through the kindness of Sir J. W. Dawson, F.R.S., I have been supplied with a small quantity of the original material obtained by Mr. Billings through treating fragments of rock containing *Archæocyathus* with acid, and from which the spicules were procured, which, as already mentioned, have been described and figured as probably belonging to this fossil. The coarser portions of this residual débris are irregular-shaped siliceous fragments, of a grey tint, showing in

[1] American Journ. of Science, n.s. vol. 45 (1868), p. 62; vol. 46, p. 144.
[2] Life's Dawn on Earth, p. 154.
[3] Lethæa Palæozoica, p. 301.
[4] Versteinerungen der Insel Sardinien (1886), p. 28.
[5] Cambrian Faunas of North America, Bull. No. 30, U.S. Geol. Surv. (1886), p. 72.
[6] Zeitsch. d. deutsch. Geol. Gesellsch. 1886, p. 899.
[7] Thus we find one of the latest writers on it, Mr. C. D. Walcott, stating that the presence of spiculæ in this species associates it with the Spongiæ, close to the family Euretidæ of Zittel, and he considers that the spiculæ "in several of the species have been lost in the crystallization of the calcite now forming the skeleton," *l.c.* p. 80.

places on their outer surfaces small rounded granules like those of Beekite. The fragments are in part porous, and several of them are filled with fragmentary spicules dispersed irregularly in the rock, and apparently in various stages of dissolution. In the finer débris are smaller particles of silica and detached entire and broken spicules. From these I have picked out fairly complete fusiform acerate spicules (Fig. 1, *b*, *c*, *d*), acuate or pin-shaped spicules (*a*), and portions of nearly cylindrical forms (*e*). The spicules are of chalcedonic silica, and their axial canals are preserved in many instances. They are common types of siliceous monactinellid spicules, and belong to at least four species of sponges. Forms of a similar character, and similarly detached, are very abundant in the cherty beds of the Yoredale rocks of Yorkshire. I have but little doubt that these siliceous fragments from the Mingan strata, in which *Archæocyathus* occurs, have been produced by the dissolution of the spicules of disintegrated monactinellid sponges, and the redeposition of the silica as Beekite.

I have not, however, detected in the débris examined a single fragment of the so-termed 'branching spicula' (Fig. 1, *f*–*i*), described and figured by Billings as forming part of the substance of the outer wall of *A. Minganensis*. Judging from the figures given of them, I do not think they can be regarded as spicules; they are merely abruptly broken fragments of what appears to have been a delicate continuous porous membrane; no two of them are similar, and they do not bear any definite resemblance to any sponge spicules with which I am acquainted. I have no doubt that—as stated—they form part of the outer wall of *Archæocyathus Minganensis*, but instead of being 'branching spicula,' they are merely broken portions of the calcareous tissue of the outer wall, replaced by silica. The structure of the outer wall in the allied species *A. Whitneyi*, Meek, is described[1] as consisting of minute punctures so closely crowded that the little divisions between them are scarcely equal in breadth to the punctures themselves, and form, as it were, an extremely delicate kind of network, and the so-termed 'branching spicula' in *A. Minganensis* might well be broken-up portions of a network of this character.

Therefore as regards the true sponge-spicules associated with *A. Minganensis*, it is evident there is no other connection between them and this species than the accident of position, and the so-termed branching spicula, which really belong to this fossil, are in all probability mere siliceous replacements of the tissue of its outer wall. Thus in neither case is there any evidence in support of the view that *Archæocyathus* is allied to *siliceous* sponges. My knowledge of this puzzling fossil is insufficient for me to give a competent opinion as to its real nature; it is fairly certain, however, that its skeleton was originally calcareous, and it is just possible that careful microscopical examination might give a clue to its relations.

[1] American Journ. Sci. vol. xlv. p. 62.

NOTICES OF MEMOIRS.

I.—On Two New Forms of Polyodont and Gonorhynchid Fishes from the Eocene of the Rocky Mountains. By Prof. E. D. Cope. Mem. Nat. Acad. Sci., vol. iii. pp. 161–165, with double plate.

In 1883 (Amer. Nat. p. 1152) and again in 1885 (*ibid.* p. 1090), Prof. Cope briefly noticed a portion of the trunk of a fish from the Eocene of Wyoming, displaying many points of resemblance to the living Acipenseroid *Polyodon*, but remarkable on account of its possession of distinct scales, not confined to the upper lobe of the tail. The genus and species received the name of *Crossopholis magnicaudatus*, and in the present memoir Prof. Cope adds a detailed description, with figures, making known also a considerable portion of the skull of the fish. In many respects, the cranial bones are very similar to those of *Polyodon*, but the snout is relatively shorter, and more closely corresponds in form to that of *Psephurus*. The body is long and slender, with short dorsal and anal fins, remotely situated, and the former commencing slightly in advance of the latter. The scales are numerous, in oblique series, not quite in contact; and each consists of a small subquadrate disk, with a row of long, sharp, backwardly-directed spines arranged upon the posterior margin. In an individual measuring 0·170 m. from the anterior extremity of the dorsal fin to the notch of the caudal, the scales only measure about one millimetre each way: the caudal fulcra are large and strong. Another novelty from the Wyoming shales first noticed by Prof. Cope in 1885 (Amer. Nat. p. 1091) is also figured and described in detail, namely, the *Notogoneus osculus*. This is of great interest as being scarcely distinguishable from the living *Gonorhynchus*, except in the dentition; for the latter genus—the only representative of its family previously known—is solely confined to the seas of South Africa, South and Western Australia, and Japan. As well remarked, "The discovery of this type in the Eocene beds of North America is a notable addition to ichthyological science. It is parallel with the occurrence of the family of the Osteoglossidæ in the same formation, a family also now confined to the Southern Hemisphere." The memoir concludes with a figure and description of a small *Priscacara*, supposed to be adult and referable to a new species, *P. hypsacanthus*; and it is also added that a newly acquired specimen of *P. serrata* displays massive superior and inferior pharyngeal bones, covered with obtuse grinding teeth. A. S. W.

II.—Eocene Chelonia from the Salt Range. By R. Lydekker, B.A., F.G.S. Palæont. Indica, ser. 10, vol. iv. pp. 59—65, plates xii. and xiii. 1887.

Two interesting Chelonian fossils were obtained from the Lower Eocene of Nila, in the Punjab Salt-Range, by Dr. H. Warth, in 1886, and presented by him to the Indian Museum, Calcutta. These form the subject of the present memoir, and are interesting as being the only known Indian Chelonia of earlier date than those

of the Siwalik period, with the exception of the small *Platemys Leithi* from the inter-trappean beds of Bombay. The first specimen described comprises the greater portion of the carapace and plastron of a Pleurodiran Chelonian, characterized by the absence of epidermal shields. In the latter feature it agrees precisely with the genus *Carettochelys*, recently discovered by Dr. E. P. Ramsay in the Fly River, New Guinea, and may therefore be placed in the family of *Carettochelyidæ*, as defined by Boulenger; its generic distinctness, however, is indicated by the neural plates being in contact, not separated by the costals, and also perhaps by the presence of a mesoplastron. The plastron is marked by a pitted sculpture, and the genus and species receives the name of *Hemichelys Warthi*. The second fossil is much less complete than the first, and is provisionally referred to a new species of *Podocnemis*, under the name of *P. indica*. The greater portion of the carapace is preserved, and its total length would probably be about 35 inches; it is oval, tectiform, not keeled, and narrowed posteriorly. Though now confined to South America, the occurrence of *Podocnemis* and *Platemys*, in the Indian Tertiaries, is not an altogether unexpected fact, the former, at least, also being met with in the Lower Eocene of England; and, as Mr. Lydekker remarks, the available evidence now seems to point to the conclusion, that the original habitat of this group of fresh-water Chelonia was in the northern portion of the Old World, whence they have been driven perhaps by the competition of the Emydians. A. S. W.

III.—Om Postglaciala aflagringar med *Ancylus fluviatilis* på Gotland. Af Henr. Munthe. Öfversight af Kongl. Vetensk.-Akad. Förhandlingar, 1887, No. 10, pp. 719–732.

On Post-Glacial Deposits with *Ancylus fluviatilis* on the Isle of Gotland. By Henry Munthe.

DURING the last three summers the author of this paper has been investigating the Quaternary deposits of the Isle of Gotland, and he has discovered in various localities shore-deposits or raised beaches (Strandvallar) at different elevations up to 150 feet above the present sea-level, which contain the shells of freshwater mollusca exclusively, more particularly of *Ancylus fluviatilis* and *Limnæa ovata*. These deposits consist of rounded stones, coarse and fine gravels, and intercalated beds of fine sand, they are chiefly rearranged glacial deposits formed from the limestone of the district. The shells usually occur in the layers of sand. In 24 localities examined, the *L. ovata* is found in all save one, and the *Ancylus* in 19, whilst species of *Pisidium* are present in 10. Other species of less frequent occurrence are *Limnæa palustris*, *Planorbis contortus* and *marginatus*, *Valvata cristata* and *Bythinia tentaculata*, with some Ostracoda. The shells are usually well preserved.

Some of these raised shelly beaches are situated on the summits of partially or entirely isolated limestone plateaux, where there is not the least ground for supposing the former existence of small

freshwater lakes, nor is there any possibility that the shells can have been washed into the sea by rivers and then re-deposited in the beaches. The author believes that these beaches were formed at a time when the Baltic was a freshwater sea containing a molluscan fauna whose principal representatives are the above-named species of *Ancylus* and *Limnæa*.

There are also on the Isle of Gotland raised beaches of marine origin containing *Litorina*, etc., which are seldom at a higher level than 50 feet, though one has been described by Lindström near Wisby, which is 80 feet above the sea-level. The marine raised beaches are, however, at a distinctly lower level than those with freshwater shells, and must have belonged to a later period, when the freshwater fauna had been supplanted by marine forms.

Shell-beaches of a similar character and relative position, and containing the same freshwater mollusca, have been described by Friedr. Schmidt in Esthonia and on the islands of Ösel and Mohn, but this author regards them, in part at least, as river-deposits, although there are no distinct traces of old river-beds in the localities where they occur.[1] Prof. James Geikie has also referred to these Russian deposits as indicating that the Gulfs of Finland and Bothnia were freshwater seas at the close of the Glacial period.

Further discoveries are requisite before it is possible to lay down approximately the limits of the Baltic at the time when these Gotland freshwater beaches were formed, or to ascertain the nature and position of the barrier which dammed its waters 150 feet above their present level; but the author concludes that its northern half at least, together with the Gulfs of Finland and Riga, formed at the time a single freshwater basin. G. J. H.

REPORTS AND PROCEEDINGS.

Geological Society of London.

I.—March 28, 1888.—W. T. Blanford, LL.D., F.R.S., President, in the Chair.—The following communications were read :—

1. "On some Eroded Agate Pebbles from the Soudan." By Prof. V. Ball, M.A., F.R.S., F.G.S.

The majority of the pebbles in a collection made by Surgeon-Major Greene in the Soudan, and presented by him to the Science and Art Museum in Dublin, are of very similar character to the agate and jasper pebbles derived from the basalts of India. It may be concluded inferentially that they came originally from a region in which basaltic rocks occur to a considerable extent. A certain number of them are eroded in a manner unlike anything noticed in India, though it is probable that similar eroded pebbles will eventually be found there.

Throughout India, wherever there is deficient subsoil-drainage or excessive evaporation and limited rainfall, salts are apparent either in supersaturated subsoil-solutions or as crystallizations in

[1] Prehistoric Europe, p. 470.

the soil. They are most abundant in basaltic regions, and in a lake occupying a hollow in the basalt in Berar carbonate of soda is deposited in abundance from the water, which becomes supersaturated during the summer.

The author commented on the efficacy of such a liquid as a solvent of silica, and noticed the selective action of the agent which had affected the Soudan pebbles and had corroded some layers more than others; he suggested that while this might be to some extent due to differences in composition, it was more probably owing to differences of nodular constitution. He considered it unnecessary to refer to the action of humic acid, because while the salt to which the solvent action is attributed would be capable of doing such work, and would be probably abundant in the region referred to, we could not expect any great amount of humic acid in the same area.

2. "On the Probable Mode of Transport of the Fragments of Granite and other Rocks which are found imbedded in the Carboniferous Limestone of the Neighbourhood of Dublin." By Prof. V. Ball, M.A., F.R.S., F.G.S.

Angular fragments of granite and of schist, quartzite, and vein-quartz, such as might have been derived from the metamorphosed rocks which rest on the granite near Dublin, have been discovered in beds of Carboniferous Limestone, which often contain fragments of fossils, especially Encrinites. They have been previously noticed by Professor Haughton, Mr. H. B. S. Montgomery, Prof. Jukes, and Mr. Croll. While Prof. Jukes refers their transportation to the agency of land-plants, Mr. Croll quotes their occurrence in support of his argument as to the existence of glacial conditions during the Carboniferous period.

The author observed that the specimens exhibited none of the indications of the existence of glacial conditions, whether we regard the characters of the boulders or the nature of the rock in which they are imbedded, which contains no such silt as that occurring in the boulder-bed of the Talchir formation. Whilst rejecting the view that they were transported by ice, he pointed out that they need not necessarily have been carried by land-plants, but that they might have been torn from the sea-floor by marine algæ, some of which may have had a more buoyant character than those of modern seas. He cited the case of a sandy beach in the neighbourhood of Youghal, which is strewn with limestone fragments, which had been conveyed by seaweeds thrown up after storms from submarine banks.

It was suggested that the occurrence of natural fissures in the rocks and cracks produced by concussions from large masses hurled about by the waves might sufficiently explain how the fragments could be freed from the main mass of the reefs under the stress of the waves.

3. "The Upper Eocene, comprising the Barton and Upper Bagshot Formations." By J. Starkie Gardner, Esq., F.G.S., and Henry Keeping, Esq., with an Appendix by H. W. Monckton, Esq., F.G.S.

The familiar Upper Eocene having been transferred to the Oligocene, the remaining uppermost division of the Eocene bears the title Middle. Unless the considerable literature relating to the Brackle-

sham, the Calcaire Grossier, and the Nummulitic, is to be rendered obsolete, their classification as Middle Eocene must be preserved, and a modified Upper Eocene constructed out of the Barton series. The authors' proposal is that the following should be adopted :—

	London Area	Hampshire Area.
Upper Eocene	———	Upper Barton.
	———	Middle ,,
	Upper Bagshot Sands.	Lower ,,

The base of the formation is not sharply defined, but it coincides with the final disappearance of several subtropical Mollusca, and almost with the extinction of Nummulites in our area. The upper limit is drawn at the base of the Lower Headon, where the brackish fauna gives place to one of fresh water.

The conditions of deposition were examined at some length, and evidence in support of the estuarine origin of the formation was adduced. The section in Christchurch Bay was described first, and the thickness and characteristics of each subdivision given, the total reaching 170 to 180 feet. It commences with 45 feet of whitish sand, and, in ascending order, a pebble-bed, 11 feet of greenish clay, and a band of imperfect ironstone underlying the zone of *Nummulites elegans*. Then 20 feet of stiff drab clay, 13 feet of drab clay with sand-drifts, and 12 feet of the same, known as the Highcliff Sands. The Lower Barton terminates with the *Pholadomya*-bed. The fauna of this division comprises many Bracklesham species, which range no farther up, and a large number of peculiar species. The most convenient base-line for the Middle Barton is the lowest of several bands of Septaria, which distinguish the 50 feet of drab clays which are comprised in it, and it terminates in a very remarkable formation known as the shell-bed, which, though only a foot or two thick at Highcliff, thickens to about 15 feet to the east, and to 22 feet in the new Christchurch cutting. The finest Barton fossils are obtained from the Middle division ; but though so many splendid species characterize it, few are absolutely confined to it. The upward range of a further number of Bracklesham species ceases at the shell-bed. The Upper Barton includes the *Chama*-bed, the Becton Bunny and the Long-Mead-End beds.

The Becton Bunny beds, 52 feet thick, are sand in the lower half and sandy clay above—*Oliva Branderi* is the characteristic fossil, and a large number of bivalves and brackish Headon Gasteropods come in. Opinions have differed considerably as to whether these beds should be included in the Bartons. The series closes with the Long-Mead-End Sands, 20 feet thick, with similar fossils, and formerly known as the Upper Bagshot Sands of the Hampshire basin. The section is continued without any break into the Lower Headon.

The next section described was that exposed in the cuttings for the new line from Brockenhurst to Christchurch, and here great changes in the relative thicknesses are seen, confirming the view that the Barton formation is the local deposit of a limited estuary. The *Chama*-bed remains 18 feet thick, but the shell-bed thickens to 22 feet, and the drab clay with Septaria is only 10 feet. The under-

lying greenish compact clay looks like Lower Barton, but may belong to the Middle. The Upper Bartons are much weathered and unfossiliferous, but the *Paludina*-beds of the Lower Headon do not appear for 3900 yards east. Some of these, 2330 yards west of the Brockenhurst road, are violently contorted.

The Alum-Bay section was then compared with those previously given, and the authors also noticed the Bracklesham, Stubbington, and Hunting-Bridge sections to show the transitional character of the highest of the Bracklesham beds. The paper concluded with an analysis of the fauna, and carefully revised and tabulated lists.

Mr. Monckton, in his Appendix, stated that in the London basin the Barton beds are represented by the Upper Bagshot Sand, a mass of yellow or nearly white sand without clay-beds, though often loamy. Its greatest proved thickness is 228½ feet, and the base is marked by a very persistent bed of pebbles.

Its extent is considerably greater than is shown on the Geological Survey map.

Casts and impressions of shells are abundant in some places, but recognizable species have only been found at Tunnel Hill near North Camp Station, Aldershot. A large collection from this place has been made by Mr. Herries and by the author.

II.—April 11, 1888.—W. T. Blanford, LL.D., F.R.S., President, in the Chair.—The following communications were read :—

1. "On the Lower Beds of the Upper Cretaceous Series in Lincolnshire and Yorkshire." By W. Hill, Esq., F.G.S.

The Red Chalk which forms the basement-bed of the Upper Cretaceous in Lincolnshire and Yorkshire is a continuation of the Hunstanton Limestone. Its thickness increases in South Lincolnshire to thin away again in the north of that county; but it again increases north of the Humber for a while. Near its most north-westerly exposure on the Yorkshire Wolds the red colour is lost; but *Inoceramus sulcatus* and *Belemnites minimus* are found in a dirty yellow-coloured material of trifling thickness. Eastwards it regains its red colour and thickness, so as to be upwards of 30 feet at Speeton, where also it is less calcareous. This section was described in detail, and the results compared with those of other writers. The author speculated upon the probable limits of the Upper Cretaceous sea at this period on evidence mainly based upon the amount of matter of inorganic origin. He noted that *Am. interruptus* has been found at Withcall, *Am. rostratus* at South Cave, and *Am.*? *auritus* at Wharram Grange.

The base of the Chalk Marl through Lincolnshire continues to be marked by a bed of compact limestone, which is the representative of the "sponge-bed" of Hunstanton. This can also be traced in Yorkshire as far as the north-western extremity of the Wolds. Above this a few feet of grey gritty chalk retain the character of the "*Inoceramus*-bed" throughout the area above mentioned. At the north-western extremity of the Wolds the main mass of the Chalk Marl has diminished in thickness, but more than recovers

this at Speeton, where, according to the chemical and microscopical evidence, there is a complete passage from the "Gault" to the "Chalk Marl." The peculiar development of the latter at Speeton was very fully described. No bed such as the Cambridge Greensand or the Chloritic Marl can be taken as a line of separation.

Throughout Lincolnshire and Yorkshire certain courses of grey-coloured chalk are recognizable on the horizon of the Totternhoe Stone: these are known collectively as the "Grey bed." Much comminuted shell and numerous Pectens characterize this bed, which is faintly recognizable even at Speeton. The "Grey bed" determines the upper limit of the Chalk Marl. The equivalents of the Grey Chalk vary less in thickness throughout the area than those already described. Certain lithological characters, which first begin to manifest themselves in the marly beds just above the Totternhoe Stone in Norfolk, become greatly developed in South Lincolnshire, and throughout that county, as in Norfolk, the Grey Chalk is usually of a marly nature. In Lincolnshire there is much red colouration on this horizon. The occurrence of *Belemnitella plena* in Lincolnshire has been recognized. The band of bluish black clayey material in which it occurs at Barton continues throughout Yorkshire, but no Belemnite has yet been found. Allusion was made to the characteristic features towards the base of the Middle Chalk. Lists of fossils were given, and a new species of *Holaster* (*H. rotundus*) was described. Numerous chemical analyses and microscopic details of structure were also given.

2. "On the Cae-Gwyn Cave, North Wales." By Henry Hicks, M.D., F.R.S., F.G.S., with an Appendix by C. E. De Rance, Esq., F.G.S.

The author gave an account of the exploration of the cavern during the latter part of 1885, and during 1886–7. He considered that the results obtained during that time proved conclusively that there was no foundation for the views of those who contended that the drift which covered over the entrance and extended into the cavern was *remanié*, but they proved that the deposits which lay over the bone-earth were *in situ*, and were identical with the normal glacial deposits of the area. These deposits had once extended continuously across the valley, and the cavern (400 feet above Ordnance Datum) had consequently been completely buried beneath them.

The cave must have been occupied by animals during the formation of the bone-earth, before any of the glacial deposits now found there had accumulated, and a thick floor of stalagmite had covered this "earth" before the cavern had been subjected to water-action. This action had broken up the floor, and completely re-sorted the materials, and added sandy and gravelly material to the deposits; this sand and gravel had been examined by Prof. Boyd Dawkins, who found that it agreed in every particular with the glacial sand and gravel occurring in the valley a little way above. The large limestone blocks in the cavern had also been evidently disturbed by water-action; they were invariably found in the lowest deposits, and were covered over by laminated clay, sand, and gravels. The author considered it certain

that the caverns had been completely filled with these materials, and in the case of the Cae-Gwyn cave they appeared to have been conveyed mainly through the entrance recently discovered under the drift. The stratification at this entrance was so marked, and could be traced so continuously inwards over the bone-earth, that there could be no doubt that this was the main entrance. There was not the slightest evidence that any portion of the material had been conveyed in through a swallow-hole, and the conditions witnessed throughout were such as to preclude any such idea.

The author quoted a Report by Dr. Geikie, who considered that the wall of the cavern had given way, but before the deposition of the glacial deposits, which were subsequently laid down against the limestone bank so as to conceal this entrance to the cavern.

In conclusion, he referred to the presence of Reindeer remains in these caves, in conjunction with those of the so-called older Pleistocene mammalia, proving that these had reached the area long before the period of submergence, and evidently at an early stage in the Glacial period. It was important to remember that Reindeer remains had been found in the oldest river-gravels in which implements had been discovered. Man, as proved by the implements discovered, was also present at the same time with the Reindeer, and it was therefore natural to suppose that he migrated into this area in company with that animal from some northern source, though this did not preclude the idea that he might also have reached this country from some eastern or southern source, perhaps even at an earlier period.

Mr. De Rance, in an Appendix, confirmed Dr. Hicks's observations as to the identity of the deposits outside the cavern with those in its interior, and noted the occurrence of limestone blocks in the lower deposits, not merely at the spot where the supposed broken wall was situated, but also throughout the whole tunnel. He stated that the sand-bed forming the uppermost cave-deposit resembled the sand associated with gravels in a pit 400 yards east of the cave at a slightly higher level. The drift exposed in this gravel-pit he believed to be of the same age as that of the Mostyn and Bagillt pits to the north, which were undoubtedly overlain by Upper Boulder-clay. The westerly termination of the bone-earth outside the cave had not been determined, which he regretted; but traces of bone had been found at a point five feet from the overhanging ridge of the cave.

CORRESPONDENCE.

PALÆONTOLOGICAL NOMENCLATURE.

Sir,—The questions raised by the gentleman signing himself Rob. W. Haddow in the Geol. Mag. for November, 1887, and discussed by Mr. S. S. Buckman in the March number, are well worthy of further consideration in your pages.

I confess that I largely agree with Mr. Haddow in his protest against the entire suppression of the old genus *Ammonites*, and I would reply to Mr. Buckman, (1) that the genera of one family

should differ from one another in characters of equivalent value, and (2) that it is *not necessarily wrong* "to include in the same genus species descended for a long time through entirely different lines of ancestors." There is in fact very little wrong or right in the matter, it is one of convenience and of sensible proportional treatment.

We may admit that the whole family Ammonitidæ requires revision and reconstruction, and possibly that it is desirable to create a certain number of new genera out of the old genus *Ammonites*, but I join Mr. Haddow in protesting against the infinite subdivision which some palæontologists are trying to force upon us. The old principles of classification may not be defensible, but is it so very certain that some of the principles now adopted in their stead, such as the form of the mouth, are any better? Is there not some analogy between the case of the genus *Ammonites* and that of the genus *Helix*, in which an infinity of peculiar variations occur in the shells without any important differences occurring in the structure of the animals?

If mere sections and subgeneric groups are raised to the rank of genera, the old genera become tribes and subtribes, and Mr. Buckman even wants us to accept names for generic and subgeneric groups, ranking between genera and subtribes. Surely, Sir, such an arrangement as he gives us in his Monograph on Inferior Oolite Ammonites is the height of cumbrousness, and shows the absurdity to which the system is capable of being carried. Stated in full this arrangement is as follows:—

Family—Ammonitidæ.
Subfamily—Ammonites (note the termination).
Tribe—Ægoceratidæ.
Subtribe—Harpoceratinæ.
Generic group—Hammatoceratidæ.
Generic subgroup—Hildoceratinæ.
Genus—Ludwigia.
Species—Murchisonæ.

Really I think a trinomial or even a quadrinomial system is better than this, which is practically a septinomial one. The small section of a group which is here elevated into a genus hardly merits a name at all, it is a mere section of *Harpoceras* which may be regarded as a subgenus of *Ammonites*. I therefore take up Mr. Buckman's challenge, and would speak of the species trinomially thus—

Ammonites (*Harpoceras*) *Murchisonæ*,
„ „ „ var. *obtusa*.

By this method it would still be possible for the stratigraphical geologist to speak of it as *Ammonites Murchisonæ*, while the palæontologist who makes a special study of the genus would doubtless usually call it *Harpoceras*; but no other Ammonite could receive the same specific name, whereas, if *Harpoceras* be admitted as a generic name, new species referable to that genus might receive the same names as those now applied to other well-known species of Ammonites; thus we might have *Harpoceras cordatus*, *H. cristatus*, etc.

As regards the rectification of erroneous identifications, we are of

course indebted to Messrs. Wright and Buckman for their researches, and if necessary the names of species taken to characterise given zones must be altered in accordance with their determinations. In no department has our nomenclature yet reached perfection, and as Mr. Buckman says, we must effect changes of name as our knowledge increases, but at the same time we must agree upon general systematic principles. A. J. Jukes-Browne.

Shirley, Southampton.

GLAUCOPHANE IN ANGLESEY.

Sir,—The interesting paper by Prof. Blake, "On the Occurrence of a Glaucophane-bearing Rock in Anglesey," which appears in your March issue, suggests a question of nomenclature which is likely to give us some trouble. I am very glad to have Prof. Blake's support in assigning an igneous origin to some of the Anglesey schists; but now that they are schists I should hesitate to call them "igneous." In Prof. Bonney's description (quoted by Prof. Blake) of a specimen from the Anglesey column, the constituent minerals are "probably a species of chlorite," "epidote," "quartz (?)," and "mica"; and they form "a foliated dense felted mass." According to my view, in which I understand Prof. Blake to acquiesce, this rock was once a diorite (hornblende and plagioclase). If so, the change from the eruptive rock to the schist is surely entitled to be called a metamorphosis. If we apply the term "igneous" to a crystalline schist when we can assign to it an eruptive origin, must we call it "aqueous" when we know it was once a sediment? And under what head must we class it when its genesis is unknown to us? I grant that in tracing a diorite or a granite into a schist, we cannot fix a hard boundary-line between the two; but a similar difficulty meets us in the study of metamorphosed sediments, and it is not found to be very serious. However, I write rather to raise a question than to settle it. If we are not to call crystalline schists by the term "metamorphic," how shall we designate them? They would be as sweet to me by any other name.

Wellington, Salop. Ch. Callaway.

THE ATMOSPHERE OF THE COAL-PERIOD.

Sir,—In the review of the 2nd Vol. of my treatise on Geology which appeared in the last number of your Magazine, your reviewer remarks (p. 161), "The author considers that, during the Coal-period, the atmosphere was more dense, and more charged with moisture and carbonic acid, and he is led 'to conclude that the coal-growth was in all probability one of extreme rapidity, and consisted of woods and plants containing a much larger proportion of carbon than any existing forest vegetation.' With regard to the excess of carbonic acid gas, Mr. Carruthers has expressed an adverse opinion, and experiments made on living plants have shown that they are liable to be poisoned, like animals, by an excess of the gas." A footnote to this passage refers to Geol. Mag. 1869, p. 300, and 1871, p. 497. The first is a

paper "On the Forests of the Coal Period," in which he remarks that the plants "grew in extensive level plains. . . . The moist atmosphere (*not at all likely to have been charged with more carbonic acid gas than that of our own day*) [1] would encourage the growth of cellular parasites, etc." The second reference is to a paper by Dr. H. Woodward, "On Old Land Surfaces," in which, after quoting some remarks by Dr. Sterry Hunt to the effect that the atmosphere of the Coal period contained, as originally suggested by Brongniart, a "comparatively large amount of carbonic acid," he adds in a footnote, "Later experiments have, however, proved that plants, like animals, are at once poisoned by an excess of carbonic acid." Now the first reference appears to me only the expression of an opinion, and in the second, although experiments are mentioned, the reference is not given. I know of no such experiments, and if your reviewer or any of your correspondents can refer me to any, I shall feel very much obliged. The only experiments bearing on the subject, and which show that plants can live, flourish, and grow rapidly in an atmosphere with an excess of carbonic acid, I have quoted (p. 120), and I know of no others. Excuse the length of this letter, but I am anxious for information on this point, and should be glad of confirmation or otherwise on this subject, which is one of much theoretical interest.

Darent-Hulme, Shoreham, Sevenoaks, 10*th April*, 1888. Joseph Prestwich.

SPURIOUS FLINT IMPLEMENTS.

Sir,—Will you kindly allow me space in the Geol. Mag. to inform its readers who may be collectors of Flint Implements, that there are at the present time being manufactured in London worked flints, which are stated to be genuine, but which are nothing of the sort, and at the same time to say that some of these manufactured flints have been sold to gentlemen for a high price, who are considered authorities on the subject, and I trust that should any of my readers meet with such as appear doubtful they will use their best endeavours to expose and stop such a fraud. Geo. E. East.

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ALPINE RIVERS AND BUNTER PEBBLES.

Sir,—Prof. Bonney's paper on the "Rounding of Alpine Pebbles" is a valuable contribution to a chapter of physical geology; but there are one or two considerations to which I do not think he has given sufficient recognition. (1.) Weathering of débris on the mountain-sides, which often gives a certain initial rotundity to fragments of rocks. (2.) The scouring action of sand in a mountain river. So far as I can recall my own Alpine observations, I am inclined to think that where the coarser detritus is most completely rounded, so that the pebbly form is generally produced, it has been in cases where a large proportion of sandy detritus was present also. On the other hand, I have generally found that at the mouths of

[1] The Italics are mine.

Alpine gorges where a stream has had a rapid descent, so that all, or nearly all, the sandy materials have been carried away and mutual attrition has been the chief agency called into play, the pebble-form has been the exception rather than the rule.

I look upon the *variety* of the contained fragments of the Bunter strata as one of their most important physical characters. This is not only true of such great pebble-deposits as the Budleigh Salterton Pebble-bed, and those of Sutton Park, near Birmingham; but it is even more marked in the Nottingham type of these beds, in which generally the facies presented to us is rather that of a *coarse pebbly sandstone* than that of a pebble-bed. In these we find very well-rolled pebbles of quartz and quartzite; but we also find fragments of such rocks as Millstone-grit, Coal-measure Sandstones, Yoredale Sandstones, Magnesian Limestones, along with occasional fragments and rolled masses of red Permian Marls, which, with those enumerated, can be traced to the denudation of the Pennine Highlands. These, together with the intercalated (often lenticular) marly bands formed in littoral pools, or in channels of contemporaneous erosion, are no doubt riverine in their origin; and, so far as I can recollect, are not generally worn into anything like pebbles. This certainly cannot be accounted for by their relative hardness. Facts of a similar nature in the Severn and Upper Trent country, and in Cheshire, have been recorded by Prof. Hull. I regard the strata of the Middle Bunter, where rolled detritus chiefly occurs, as a series of shore and bay deposits, in which riverine detritus from the ancient land is to be found mingled with pebbles (large and small), the latter owing their shape mainly to the action of a tidal surf and the scouring action of shore-sand. The occurrence of quartzite pebbles of Silurian rocks with (occasionally) casts of fossils of the French type (as recognized by Salter) in the Salterton pebble-bed (to the extent of something like 90 per cent.), the occurrence of similar pebbles with (occasionally) casts of Silurian forms in the Warwickshire Bunter, coupled with observations on *the work which Mr. Lee has actually done upon hard rock-fragments as they are driven along shore by the roll of a tidal surf* (*e.g.* between Clovelly and Westward-Ho), seem to me to tell rather of shore-action than of river-action as the main factor concerned in the production of the Bunter pebbles. The "pebbly sandstone" type of the Middle Bunter is that which represents the normal facies, the pebble-beds proper being quite local. The two types, however, pass laterally into one another; and the main factor concerned in their differentiation was probably the local trend of the shore-line in relation to the general direction of the tidal flow. Prof. Hull's memoir, "The Permian and Triassic Rocks of the Midland Counties of England," is a mine of facts which bear out this view.

A. Irving.

Wellington College, Berks.